WHY YOU'RE AFRAID OF THE DARK

HOW IT WORKS™

SCIENCE ENVIRONMENT TE NSPORT HISTORY SPACE

THE SCIENCE OF FOOTBALL
THE TECH & TACTICS BEHIND TOP TEAMS

INTERSTELLAR SPACE TRAVEL
How we will sail to the stars at 100 million mph

ANIMAL INVASION
The places on Earth where critters have taken over

+ STAR TREK GADGETS that actually exist

SEEK & DESTROY
SUPER SUBMARINES
THE INCREDIBLE TECH POWERING THE WAR BENEATH THE WAVES

JOURNEY TO JUPITER
Everything you need to know about NASA's JUNO mission

+ LEARN ABOUT

- LIGHTHOUSE LENSES
- VICTORIAN SURGERY
- DYSON HAIR DRYER
- BEACH CLEANERS
- AIRBUS JETLINERS
- ANCIENT BURIALS
- PETROL STATIONS
- TRAIN DRIVERS
- FIGS & WASPS
- BIRD EGGS
- AVOCADOS
- CLOUDS

ip IMAGINE PUBLISHING
DigitalEdition
GreatDigitalMags.com
ISSUE 87

Butlin's
presents
THE ASTONISHING FAMILY
SCIENCE
WEEKEND

Inspiring the next generation of scientists

mumsnet
familyfriendly
GOLD
WINNER
2015

Science
Weekend
breaks from
£75
per person

GASTRONAUT

All included on The Astonishing Family Science Weekend

Aardman Animate It Live ◆ Brainiac Live ◆ Science Museum Live ◆ Gastronaut Live ◆ Code Breaking
National Space Centre ◆ Splash Waterworld ◆ Traditional Fairground ◆ Live evening entertainment

Visit **BUTLINS.COM/SCIENCE** call **0330 100 9329** quote **HOW16** book by **TUES 28 JUNE**

Price shown is per person per break based on a family of four sharing a Silver self-catering apartment for three nights on 10 June 2016 at Skegness and includes all discounts and £s off. Price is correct as of 24.05.16 but is subject to availability. All offers are subject to promotional availability, may be withdrawn at any time and cannot be combined with any other offer or internet code except the 5%Premier Club loyalty discount. Book by Tuesday 28 June. For full terms and conditions please visit butlins.com/terms. The maximum call charge is 4p per minute from a BT landline. Calls from other networks may vary. Butlin's Skyline Limited, 1 Park Lane, Hemel Hempstead, Hertfordshire, HP2 4YL. Registered in England No. 04011665.

ISSUE 87

WELCOME

The magazine that feeds minds!

> "By 2050, 'active skin' will allow computers to link to the nervous systems of players"

The science of football, page 44

Meet the team…

Jo
Features Editor
For my last issue of **How It Works**, I explored the underwater world of submarines. Now I'm off to find a yellow one to live on. Bye! x

Jackie
Deputy Editor
Dammit Jim! I'm a physicist, not a gadget expert! But as it's *Star Trek*'s 50th anniversary, I'll make an exception. Check out some real-life *Trek* tech on page 52.

Katy
Research Editor
Following the science of fear feature, the team has encouraged me to take part in exposure therapy to cure my phobia of writing magazine welcome messages.

Duncan
Senior Art Editor
I just wanted to shout my mouth off about the amazing football tech that's in this issue. Also, try tackling the in-depth reasons behind our strangest phobias.

Briony
Assistant Designer
From cat island in Japan to pig beach in the Bahamas, find out what happens when animals take over. It's great holiday inspiration!

© Adidas

FOLLOW US… How It Works magazine @HowItWorksmag

https://vk.com/readinglecture

The ocean covers more than 70 per cent of the surface of our planet, so it's no wonder we're fascinated with what lies beneath. Whether we're scouring the depths for treasure, studying strange marine creatures or using it as cover in warfare, human beings have strived to develop the apparatus to take us further, and deeper, than ever before. And nothing beats the submarine.

This month, we explore these metal behemoths and find out how they support a crew for months at a time. Crammed into bunks stacked three high, working 18-hour schedules and never seeing daylight are just some of the reasons why submariners must complete rigorous psychological tests before plunging to the depths.

If being in dark, tight spaces gives you the wiggins, flick to page 28 where Jackie will tell you why. During her research, we were sad to learn the fear that somewhere, somehow, a duck is watching you was actually made up – but if you suffer from a strange phobia, let us know!

Jodie

Jodie Tyley
Editor

CONTENTS

TRANSPORT

12 **Super submarines**
The incredible tech powering the war beneath the waves

20 Beach-cleaning machines

20 Leaves on the line

22 The world's largest passenger jet

24 A day in the life of an Underground driver

26 Refilling service stations

SCIENCE

28 **Why you're afraid of the dark**
Discover how this primal emotion is key to your survival

36 Perfect posture

38 Isolating deadly diseases

40 Seeing at sea

41 60 second science: The Doppler effect

42 The physics of dance

42 Anechoic chambers

TECHNOLOGY

44 **The science of football**
Revealed: The tech and tactics that take teams to the top

52 5 real-life *Star Trek* inventions

54 Industrial robots

56 Making medical tablets

56 Pedestrian crossings

58 The Dyson Supersonic

60 3D without glasses

60 How juicers work

ENVIRONMENT

62 **Animal invasions**
The places on Earth where critters have taken control

66 Rain clouds

66 Know your avocado

67 Figs and wasps

68 Bird eggs

SPACE

70 **Interstellar travel**

74 How SpaceX lands the Falcon 9 rocket

74 Why we search for super-Earths

75 Journey to Jupiter

76 SpaceShipTwo

HISTORY

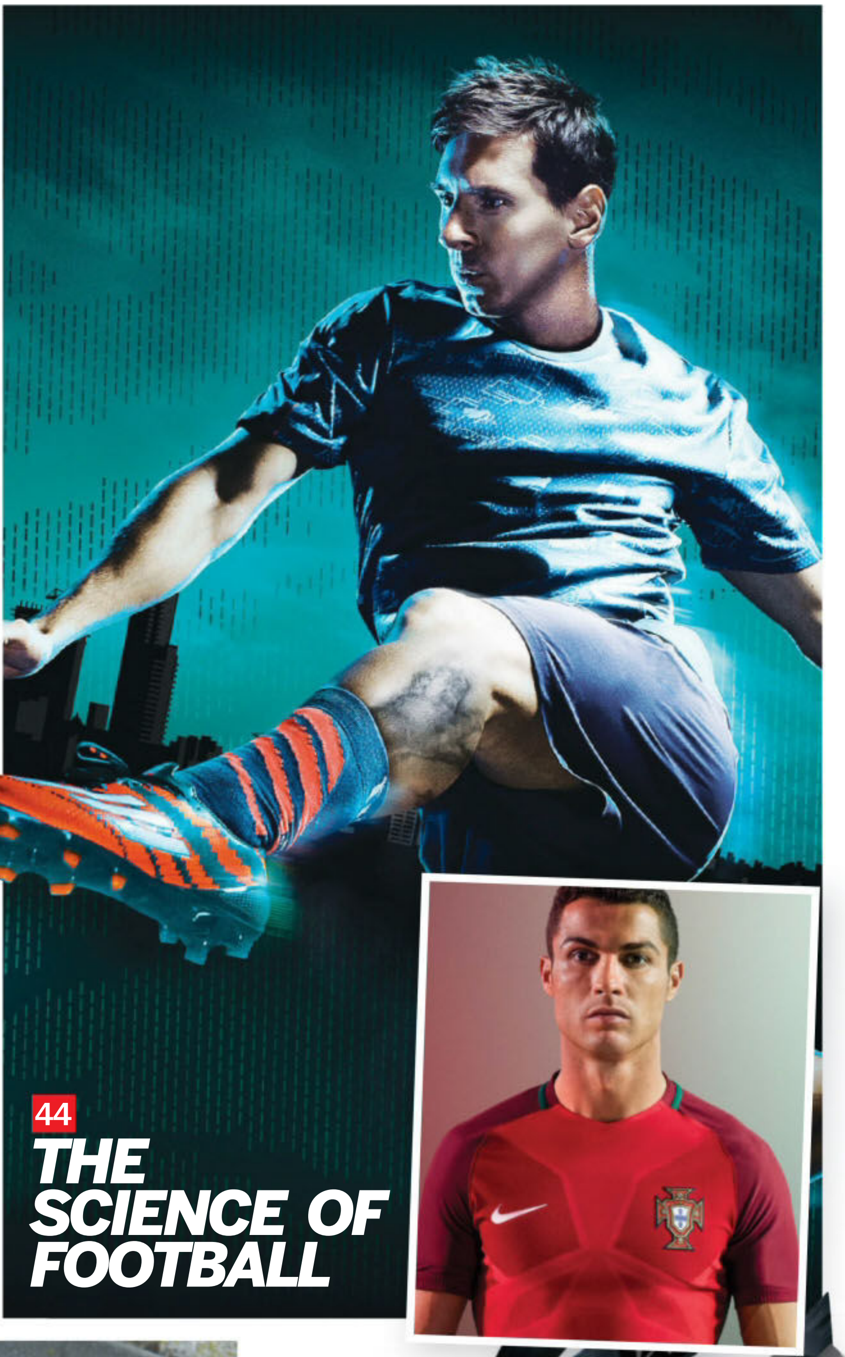
78 ***Horrible Histories'* Greg Jenner**

80 Medieval siege mining

80 Military acoustic locators

81 Ancient Peruvian burials

82 Victorian surgery



44 THE SCIENCE OF FOOTBALL

62 Animal invasions

76 SpaceShipTwo

Meet the experts…

Laura Mears
Laura donned the mask and surgical gloves to get to the heart of isolation wards – the high-security hospitals that protect us from outbreaks. She also takes a peek inside SpaceShipTwo.

Tim Williamson
The Editor of **History Of War** tells us how to capture a medieval castle and listen for the enemy – with giant trumpets! He also dug up a great story about ancient burials.

Jonny O'Callaghan
How It Works and **All About Space** readers may remember Jonny's cheeky face. These days you'll find him posting on *IFL Science*, but he found time to explain interstellar travel this issue!

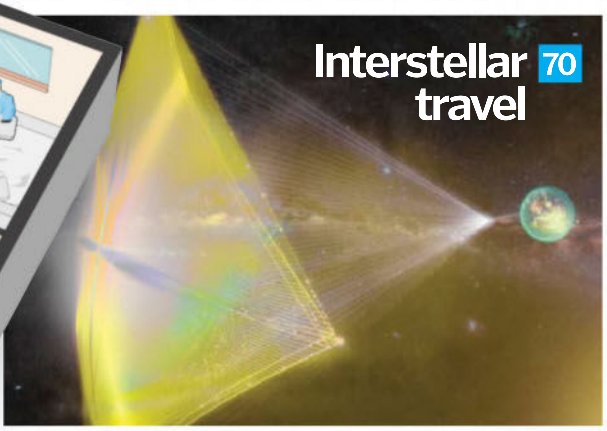
Ella Carter
Animal eggspert Ella cracks the subject of bird eggs, and also reveals the surprising relationship between figs and wasps. Beware, there's a sting in the tale…

Stephen Ashby
As a tech and footy fanatic, there was no one better to explore the future of football. Ahead of Euro 2016, learn about the game-changing tech involved.

vk.com/readinglecture

12 **SUPER SUBMARINES**

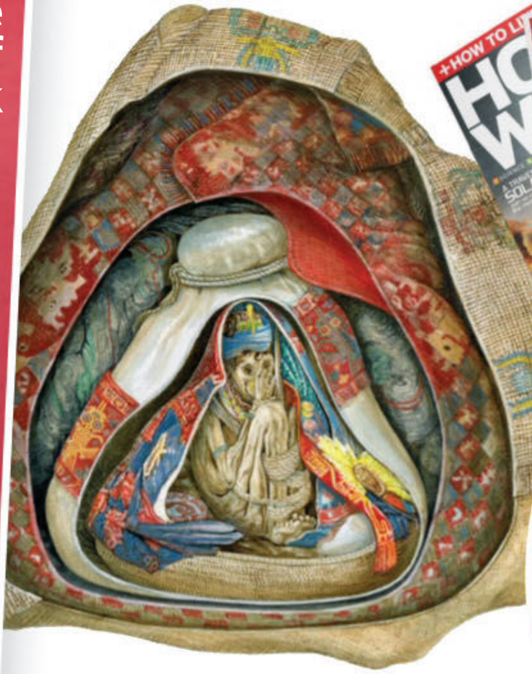
38 **Isolating deadly diseases**



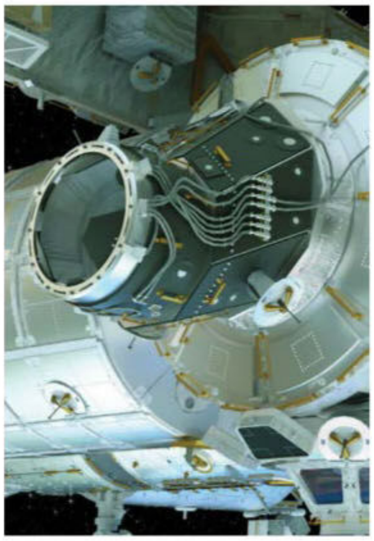
Interstellar travel 70

28 **Why you're afraid of the dark**

81 **Ancient Peruvian burials**



REGULARS



06 Global eye
Amazing science and tech stories from around the world

84 Brain dump
The place where we answer your most curious questions

90 Book reviews
Check out the latest releases for inquisitive minds

94 How to...
Make a bouncy ball and crush a can with science

96 Letters
Our readers have their say on all things science and tech

98 Fast facts
Amazing trivia that will blow your mind

HOW IT WORKS
WHY YOU'RE AFRAID OF THE DARK
SEEK & DESTROY
SUPER SUBMARINES
THE INCREDIBLE TECH POWERING THE WAR BENEATH THE WAVES
INTERSTELLAR SPACE TRAVEL
ANIMAL INVASION
JOURNEY TO JUPITER

SUBSCRIBE NOW!
Go to page 92 for great deals

Bleaching the coral reef

The Great Barrier Reef is suffering its worst coral bleaching event in recorded history

Normally a kaleidoscope of vibrant colours, much of the coral found off Australia's northeast coast is currently a ghostly shade of white. Abnormally warm ocean temperatures, a result of climate change and the current El Niño event, have led to 93 per cent of the reef experiencing coral bleaching. This is a process by which the coral expels the resident algae living within its tissue, which have become toxic in the unusually warm environment. These algae are the coral's main source of food and without them, it becomes much more susceptible to disease.

"This percentage of bleaching is unheard of and it's an enormous concern," says Jennifer Koss, director of the NOAA Coral Reef Conservation Program. "When you see a bleached reef it isn't necessarily dead yet – the coral can survive for a while just by filter feeding. But if those high water temperatures last for much longer, then the coral can't re-recruit the algae and that means mass mortality for it."

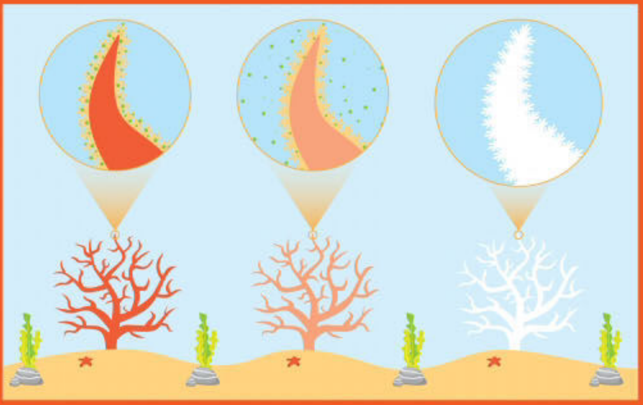
Preventing such wide-scale bleaching events from occurring again means reducing emissions and limiting global warming. However, in the meantime, researchers are looking at ways of restoring and protecting the world's reefs from current stresses. Koss explains: "We're looking at restoring reefs through coral farming, growing corals quickly to be able to plant them on a reef. Researchers are also looking at breeding 'supercorals', by figuring out which corals are the most resistant to climate change and selectively breeding them."

The recent unexpected discovery of an enormous coral reef at the mouth of the Amazon River could also prove useful for conservation efforts, as these hardy South American corals may hold the secret to surviving harsh environments. "It is tremendously exciting and I think it caught everybody off guard," says Koss. "There shouldn't be a coral reef there. The amount of sediment that comes out of the Amazon is overwhelming and the fact that there are corals that have adapted to live in this environment is huge news. There is a lot of research that needs to be done to look at what adaptations have allowed them to succeed in those waters".

NOAA uses coral nurseries to help corals recover after traumatic events

Only seven per cent of the Great Barrier Reef has escaped coral bleaching

What is coral bleaching?



Healthy coral
Microscopic algae called zooxanthellae are the coral's main food source and live inside the coral tissue, giving it its colour.

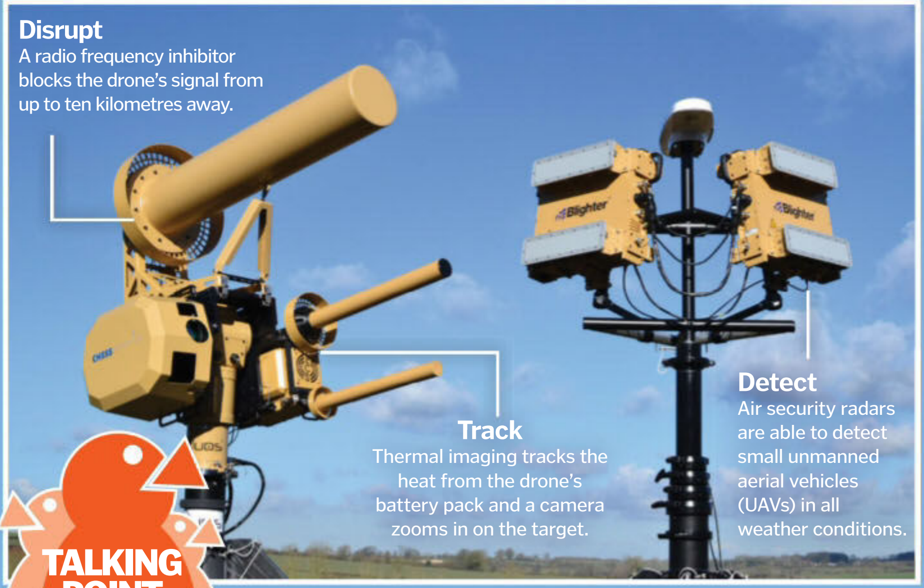
Stressed coral
When ocean temperature or pollution increases, the coral becomes stressed and expels the algae.

Bleached coral
Without the algae inside it, the coral turns white. Although it's not dead, it is more susceptible to disease.

Even small drones can cause serious damage to aircraft if they get sucked into the engines

Anti-drone death ray

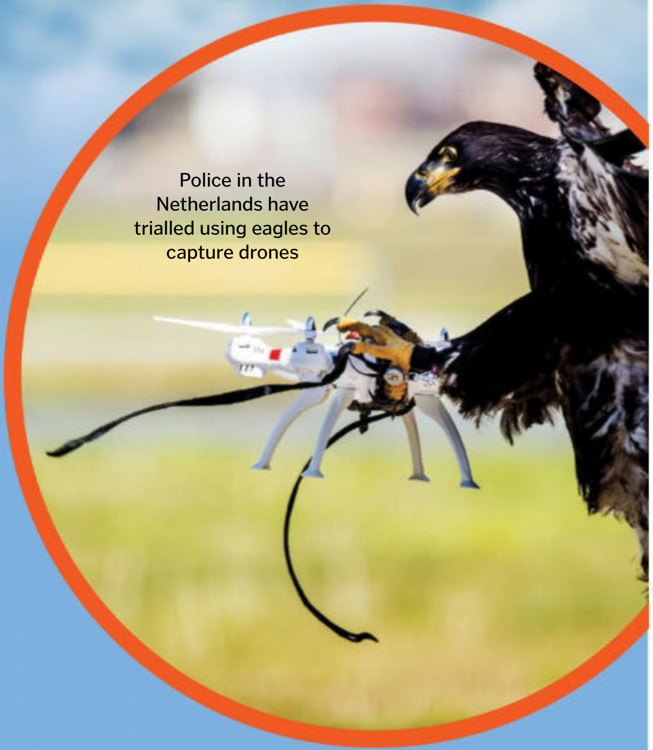
How Blighter's Anti-UAV Defence System takes down drones



Disrupt
A radio frequency inhibitor blocks the drone's signal from up to ten kilometres away.

Track
Thermal imaging tracks the heat from the drone's battery pack and a camera zooms in on the target.

Detect
Air security radars are able to detect small unmanned aerial vehicles (UAVs) in all weather conditions.



Police in the Netherlands have trialled using eagles to capture drones

TALKING POINT

INTERCEPTING DRONES

How can pilots be stopped from flying drones in restricted areas?

Stories of close encounters between toy drones and passenger aircraft are regularly in the news, sparking heated debates about whether the rules for amateur pilots should be tightened. Currently, different countries around the world have their own set of regulations for non-commercial drone flying. For example, the UK's Civil Aviation Authority states that pilots must keep their drone in sight at all times and not fly within 50 metres of buildings, people or an airport.

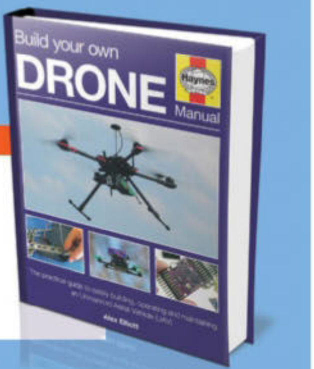
"I think the rules are quite fair but unfortunately not everyone obeys them," says drone pilot Alex Elliott. "It's a criminal offence to fly over airports but it's more of a reactive enforcement than preventative. They can only take action when somebody has already done something that they shouldn't." One countermeasure currently being trialled by the UK government is a so-called 'death ray', a military-grade technology that can jam the drone's radio signals as it approaches an airport to disable it mid-flight. "It's the easiest way to prevent drones from flying in restricted areas," Elliott continues. "However, the problem is that you might not want the drone to be disabled in the air and come crashing down. Also, planes rely on a lot of the same technologies that drones do, so if you're jamming a drone you don't want to interfere with the navigation systems of the aircraft as well."

Amazingly, birds may be the answer, as UK police forces are reportedly considering using trained eagles to intercept drones being used to break the law. "In a way I think it's the smartest method," says Elliott. "The eagle can capture and carry it down without damaging it, but we'll have to wait and see if that's really a viable solution."

> "Planes rely on a lot of the same technologies that drones do, so you don't want to interfere with their navigation systems"

Learn more

Find out how you can create your very own UAV without breaking drone regulations in Alex Elliott's book, *Build Your Own Drone*, part of the Haynes Manual series.



vk.com/readinglecture

NEWS BY NUMBERS

2018

The year SpaceX plans to launch its Red Dragon spacecraft to Mars

3 hours 35 minutes

The time it took astronaut Tim Peake to run a marathon in space

8m

The size of a giant python found in Malaysia – the longest snake ever caught

1,019 kilometres per hour

The world speed record set by the US Air Force's magnetic levitation vehicle

The GE9X engine will undergo flight testing in 2018

Record-breaking engine power

The world's biggest commercial jet engine has been fired up

Developed for the equally massive Boeing 777X aircraft, the GE9X engine can generate over 45,000 kilograms of thrust to get passengers in the air. The front fan is over three metres wide for a larger air intake, and the internal components can cope with temperatures up to 1,315 degrees Celsius. As well as being big and powerful, it is also fuel-efficient and sports the quietest engine ever produced by General Electric. It is currently undergoing testing on the ground, and is expected to enter service in 2020.

The Chicxulub crater is buried beneath 600 metres of ocean sediment off the coast of Mexico

Drilling the dinosaur crater

Looking for answers about the dino-killing asteroid impact

Sixty-six million years ago, a ten-kilometre-wide asteroid smashed into Earth, just off the coast of Mexico, obliterating almost everything on the planet, including the dinosaurs. Now, researchers are hoping to learn more about this devastating impact by drilling into the rocks of the 180-kilometre-wide crater it left behind. They are particularly interested in studying the 'peak ring' – a circle of mountains formed when the rocks on Earth's surface were pushed inwards by the asteroid, then rebounded and collapsed again.

The inflatable module is composed of an aluminium structure, layers of fabric and an internal bladder system

Inflatable space homes

The International Space Station gets an airy extension

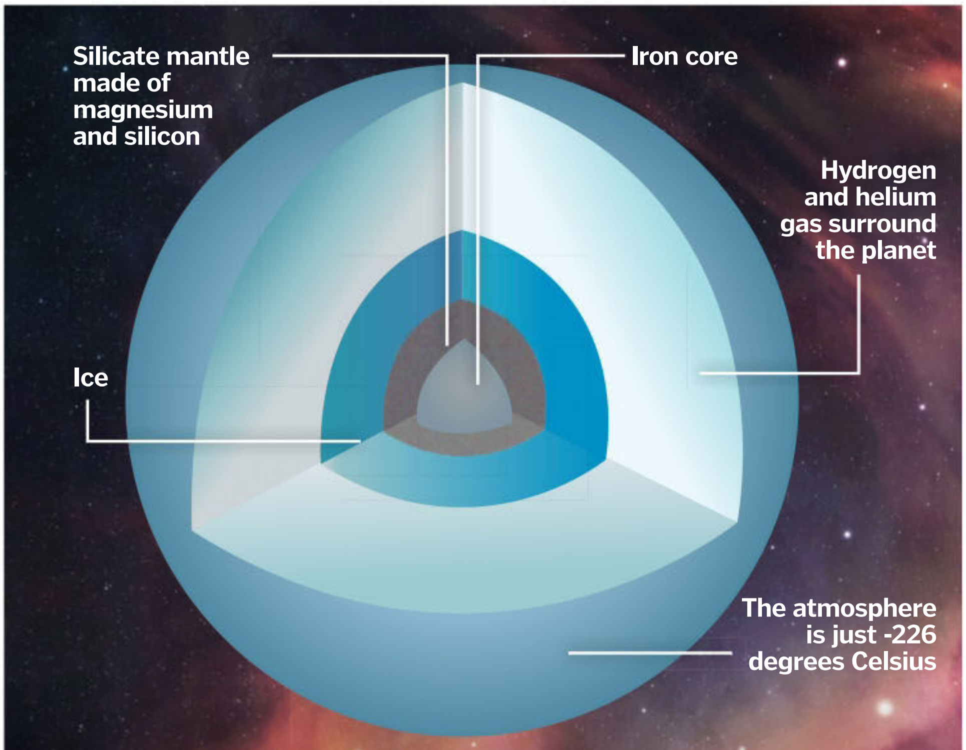
The Bigelow Expandable Activity Module (BEAM) is now firmly attached to the ISS and has become the first new addition to the orbiting space lab in five years. Secured to the station's Tranquility Node, the module was successfully inflated on the second attempt, and made sounds like popping popcorn as it expanded. ISS astronauts will monitor BEAM's performance over a two-year test period, assessing whether such structures could be used for future deep-space missions to Mars.

© hinkstock; Getty; NASA

10 COOL THINGS WE LEARNED THIS MONTH

Adrenaline junkies are born to take risks

A new study conducted by a team of US scientists has found a link between brain structure and thrill seeking. After examining 1,200 young adults, they found that those who were more likely to act impulsively and take risks had a thinner cortex (the wrinkly outer layer of the brain) around the regions involved in decision-making and self-control.

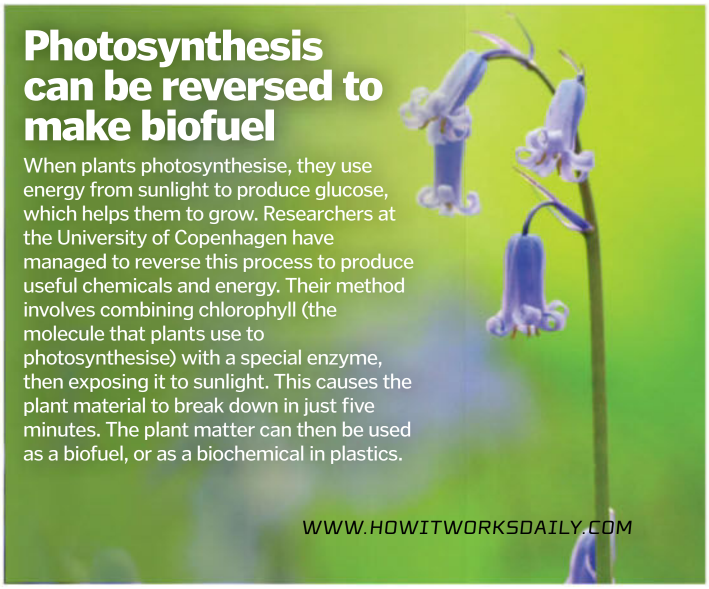

Silicate mantle made of magnesium and silicon
Iron core
Hydrogen and helium gas surround the planet
Ice
The atmosphere is just -226 degrees Celsius

Planet Nine is not very bright

Astrophysicists at the University of Bern in Switzerland have used computer simulations to work out what the newly suggested Planet Nine might be like. They predict that it is a smaller version of ice giants Uranus and Neptune – although still ten times more massive than Earth – and has a temperature of -226 degrees Celsius. They also believe that it reflects very little sunlight, explaining why telescopes have failed to detect it so far.

People with more friends have a higher pain tolerance

Endorphins (chemicals in the brain that give us feelings of pleasure and act as our body's natural painkillers) are triggered by social interactions with friends. Researchers at Oxford University conducted a study to test this theory and found that people with larger social networks did have a higher tolerance to pain, stronger than the effects of morphine.

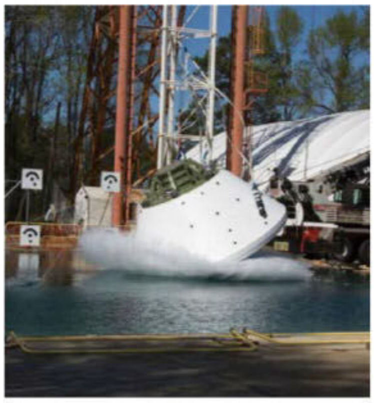


Photosynthesis can be reversed to make biofuel

When plants photosynthesise, they use energy from sunlight to produce glucose, which helps them to grow. Researchers at the University of Copenhagen have managed to reverse this process to produce useful chemicals and energy. Their method involves combining chlorophyll (the molecule that plants use to photosynthesise) with a special enzyme, then exposing it to sunlight. This causes the plant material to break down in just five minutes. The plant matter can then be used as a biofuel, or as a biochemical in plastics.

Microsoft is turning DNA into data storage

DNA stores information that defines who we are, and now Microsoft wants to use it to store digital data too. The company has purchased ten million strands of DNA on which it will encode data in order to investigate its viability as a long-term, secure storage system.

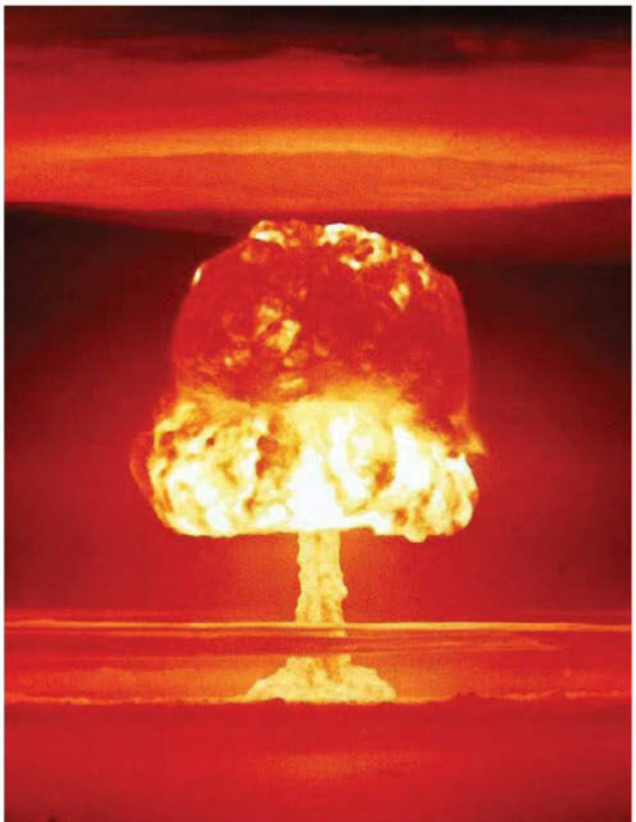


NASA has dropped its Mars spacecraft

When landing in the Pacific Ocean after a deep-space mission, NASA has conducted a series of drop tests of the Orion crew capsule, with crash-test dummies inside.

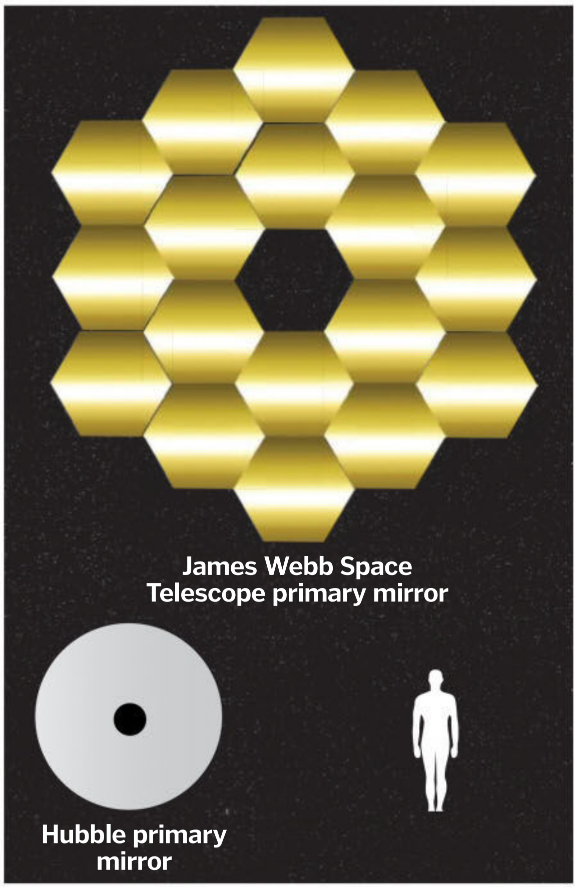
A human will join this year's great swan migration

Every autumn, thousands of Bewick's swans journey from the Russian Arctic to the UK in search of a warmer climate, but their numbers have halved in the last 20 years. To find out why, conservationist Sacha Dench will fly alongside them using a paramotor, a propeller-powered paraglider, and land with them each night to observe their habits and the hazards they face. The journey takes ten weeks to cover more than 7,000 kilometres.



Nuclear war is the biggest threat to the human race

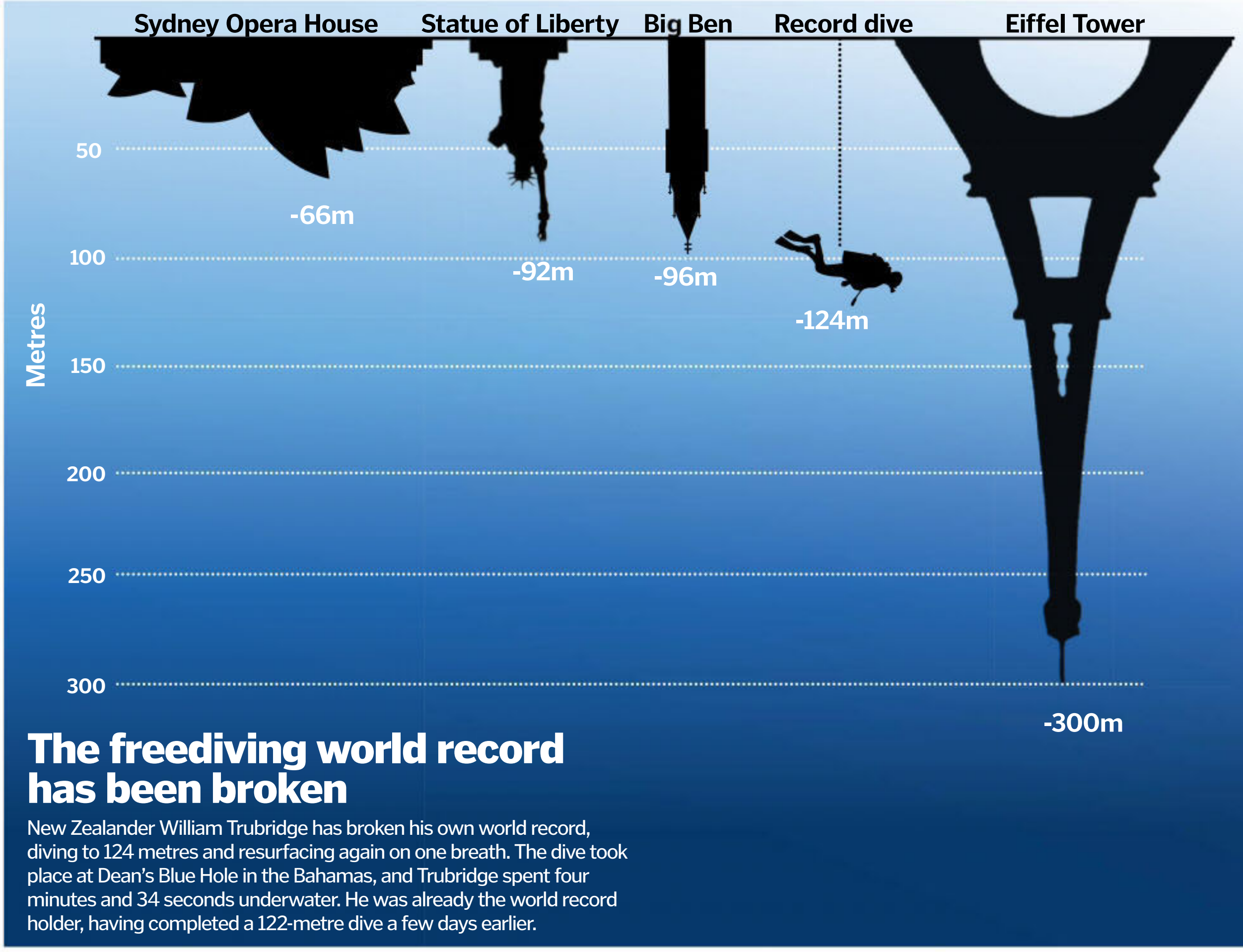
The University of Oxford's Global Priorities Project has compiled a report listing the most dangerous threats that could happen over the next five years and would result in the deaths of ten per cent of the human race. The most likely risks include nuclear war, and both natural and deliberately engineered pandemics, while climate change, the failure of geo-engineering and a takeover by artificial intelligence are deemed slightly less likely.



We'll study the universe with a giant gold mirror

Hubble's successor, the James Webb Space Telescope, will be launched in 2018, and its most important component has now been unveiled. The primary mirror will be able to collect light from the first stars to shine in the universe, and until now has been kept covered to protect its shiny gold surface from dust and scratches.

© Tesla Press image; Thinkstock; NASA



The freediving world record has been broken

New Zealander William Trubridge has broken his own world record, diving to 124 metres and resurfacing again on one breath. The dive took place at Dean's Blue Hole in the Bahamas, and Trubridge spent four minutes and 34 seconds underwater. He was already the world record holder, having completed a 122-metre dive a few days earlier.

vk.com/readinglecture

SEEK & DESTROY
SUPER SUBMARINES

THE INCREDIBLE TECH POWERING THE WAR BENEATH THE WAVES

Lurking in the depths, hundreds of submarines are currently patrolling the world's oceans, performing a range of very important, and often covert, missions. These stealthy vessels were first widely used during World War I, with Germany's U-boats responsible for destroying several British supply ships during the conflict, and have since changed the face of naval warfare forever.

Always referred to as boats rather than ships, as a matter of naval tradition, submarines have come a long way since the human-powered vessels of the past. Most modern submarines use either diesel-electric propulsion or nuclear reactors to keep them running. The former are equipped with diesel engines to drive the submarine's propellers and charge its batteries while on the surface. Then, when submerged, those batteries power electric motors that spin the propellers to move it through the water.

The need to recharge the batteries and replenish fuel for the engines gives these submarines a limited range, so many navies prefer nuclear-powered vessels instead. These

vk.com/readinglecture

DID YOU KNOW? *In 1960, the USS Triton completed the first submerged circumnavigation of the globe in 60 days*

The unmanned Boeing Echo Voyager

boats can stay underwater for weeks at a time, using nuclear fission to release energy in the form of heat, which in turn generates steam to drive a turbine and spin the propellers.

Now crucial tools for navies large and small, submarines transport crews all over the world; sneaking up on enemy ships, launching missiles, and gathering information while remaining hidden in dark, murky waters. They can generally be divided into two categories: attack submarines, which are designed to seek and destroy enemy ships, and ballistic missile submarines, which attack land-based targets. The US Navy currently has 72 submarines in active service, 54 of which are attack vessels.

It's not just the military that uses these clever underwater crafts, though. With scientists knowing more about outer space than they do about the world's oceans, submarines are incredibly useful for studying marine environments, at depths too great for human divers to reach alone.

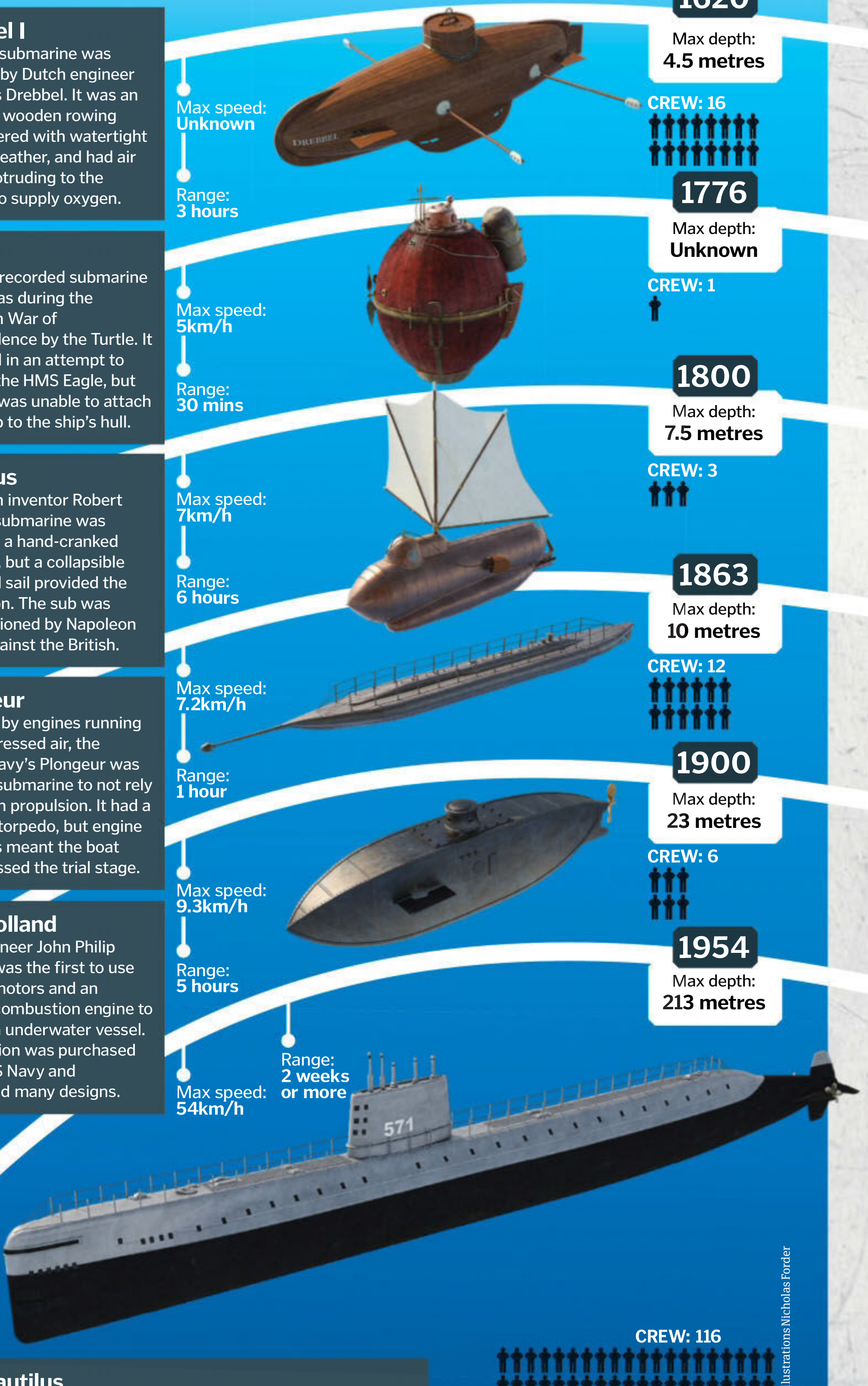
In recent years, new unmanned underwater vehicles (UUVs) have begun appearing in the water, capable of conducting dangerous missions, while human crews remain safely on the shore or a nearby ship. These vehicles are small with a limited range, but in the future they could replace the submarines we know today.

> "The US Navy currently has 72 submarines in active service"

HMS Astute firing a cruise missile

Submarines: in depth

Major milestones in the development of underwater vessels



Drebbel I

The first submarine was invented by Dutch engineer Cornelius Drebbel. It was an enclosed wooden rowing boat covered with watertight greased leather, and had air tubes protruding to the surface to supply oxygen.

Max speed: **Unknown**

Range: **3 hours**

1620

Max depth: **4.5 metres**

CREW: 16

Turtle

The first recorded submarine attack was during the American War of Independence by the Turtle. It was used in an attempt to blow up the HMS Eagle, but the pilot was unable to attach the bomb to the ship's hull.

Max speed: **5km/h**

Range: **30 mins**

1776

Max depth: **Unknown**

CREW: 1

Nautilus

American inventor Robert Fulton's submarine was driven by a hand-cranked propeller, but a collapsible mast and sail provided the propulsion. The sub was commissioned by Napoleon to use against the British.

Max speed: **7km/h**

Range: **6 hours**

1800

Max depth: **7.5 metres**

CREW: 3

Plongeur

Powered by engines running on compressed air, the French Navy's Plongeur was the first submarine to not rely on human propulsion. It had a ram and torpedo, but engine problems meant the boat never passed the trial stage.

Max speed: **7.2km/h**

Range: **1 hour**

1863

Max depth: **10 metres**

CREW: 12

USS Holland

Irish engineer John Philip Holland was the first to use electric motors and an internal combustion engine to power an underwater vessel. His creation was purchased by the US Navy and influenced many designs.

Max speed: **9.3km/h**

Range: **5 hours**

1900

Max depth: **23 metres**

CREW: 6

USS Nautilus

The first nuclear-powered submarine combined stealth and speed in order to revolutionise naval warfare. Constructed under the direction of US Navy Captain Hyman G Rickover, the 97-metre long USS Nautilus accomplished the first voyage under the geographic North Pole, and had a career spanning 25 years.

Max speed: **54km/h**

Range: **2 weeks or more**

1954

Max depth: **213 metres**

CREW: 116

© Getty; WIKI; Boeing; Illustrations Nicholas Forder

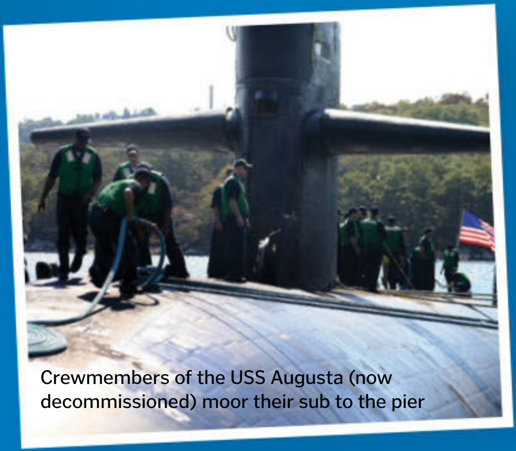
LIFE ON BOARD A SUBMARINE

How crews survive hundreds of metres beneath the sea

The job of a submariner is physically, mentally and emotionally demanding, as they can spend months at a time living in cramped conditions, with only the other members of their 100-plus crew for company. In the past, they had no means of communication with the outside world for the entire length of their mission, but today email can be used to keep in touch with loved ones at home.

Of course, the human body isn't built for life below the waves, so keeping a crew alive requires some clever technology and engineering. To protect them from the crushing water pressure, the submarine features a strong inner hull in addition to the outer hull that gives the vessel its streamlined shape.

Oxygen is supplied via pressurised tanks, or can be created on board by splitting seawater into hydrogen and oxygen using an electric current. The carbon dioxide the crew breathes out is then removed using scrubbers – devices that trap the CO_2 in soda lime using a chemical reaction. Fresh water is also created on board, as seawater can be heated to remove the salt, and then the water vapour can be cooled and condensed into a drinkable liquid.


Crewmembers of the USS Augusta (now decommissioned) moor their sub to the pier

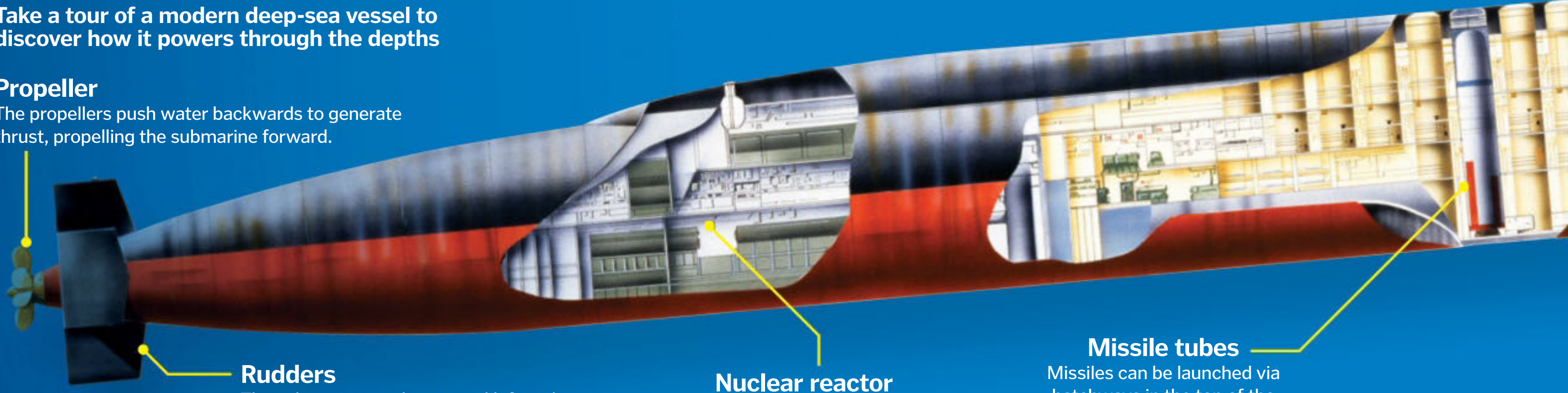
Deep-sea rescue

If a submarine is damaged, perhaps due to a collision or an onboard explosion, then the crew will radio a distress call and launch a buoy that will signal their location. Rescue will come in the form of a Deep-Submergence Rescue Vehicle (DSRV), a mini-submarine that can be transported by truck, aircraft, ship or another submarine. Once it is near to the damaged vessel, the DSRV can dive down, search for it using sonar, and then latch on to its hatch. When an airtight seal has formed, the hatch is opened and the crew can load on to the DSRV in groups of 24.

The US Navy's Deep-Submergence Rescue Vehicle, Mystic, attached to the USS La Jolla attack submarine

How a nuclear submarine works

Take a tour of a modern deep-sea vessel to discover how it powers through the depths



Propeller
The propellers push water backwards to generate thrust, propelling the submarine forward.

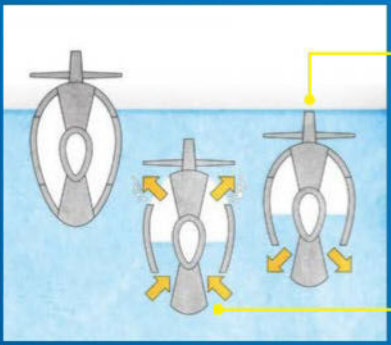
Rudders
The submarine can be steered left, right, up and down by adjusting the position of the rudders to deflect water flow.

Nuclear reactor
The reactor produces heat to generate steam, which drives a turbine that directly turns the propellers.

Missile tubes
Missiles can be launched via hatchways in the top of the submarine, sending them flying into the air and towards enemy targets.

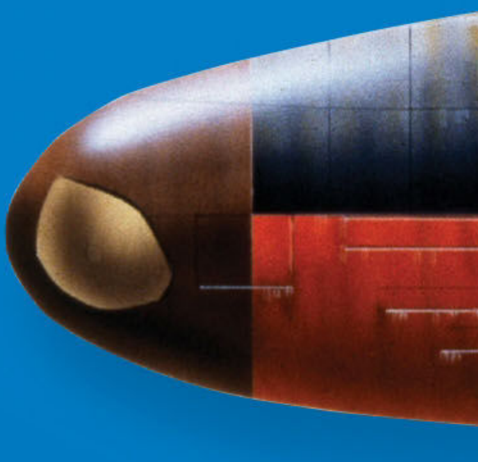
How do submarines dive?

Normally, a boat floats because the volume of water it displaces weighs the same as the boat itself. In order to sink, a submarine must weigh more than the water it displaces, creating a negative buoyancy. This is achieved by flooding ballast tanks, located between the sub's inner and outer hulls. To maintain a set depth, there needs to be a precise balance of air and water in the ballast tanks so that the sub's density is equal to that of the surrounding water.



Surfacing
The water inside the ballast tanks is pumped out and replaced with air stored in tanks, making the submarine lighter and able to surface.

Diving
Hatches are opened to fill the ballast tanks with water, making the submarine heavier than the water it has displaced, and causing it to sink.



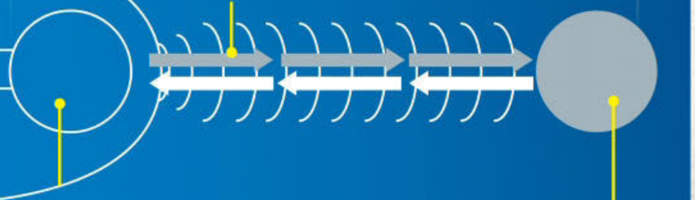
DID YOU KNOW? *DSRVs were developed as a result of the USS Thresher submarine accident in 1963, when the crew was killed*

HMS Ambush returning to its home port, HMNB Clyde

> *"Keeping a crew alive requires some clever technology and engineering"*

Underwater navigation

Little light is able to penetrate 200 metres below the ocean surface, so submarine crews use other methods to find their way. Inertial guidance systems can help to keep track of the sub's journey from a fixed starting point, using gyroscopes and accelerometers to measure changes in motion, but must be regularly realigned to ensure the vessel remains on course. On the surface, this can be done using GPS, radio and radar satellite navigation systems, but underwater, sound navigation and ranging (sonar) are used. This helps to identify ocean-floor features, allowing the crew to plot the sub's location.



Sound waves

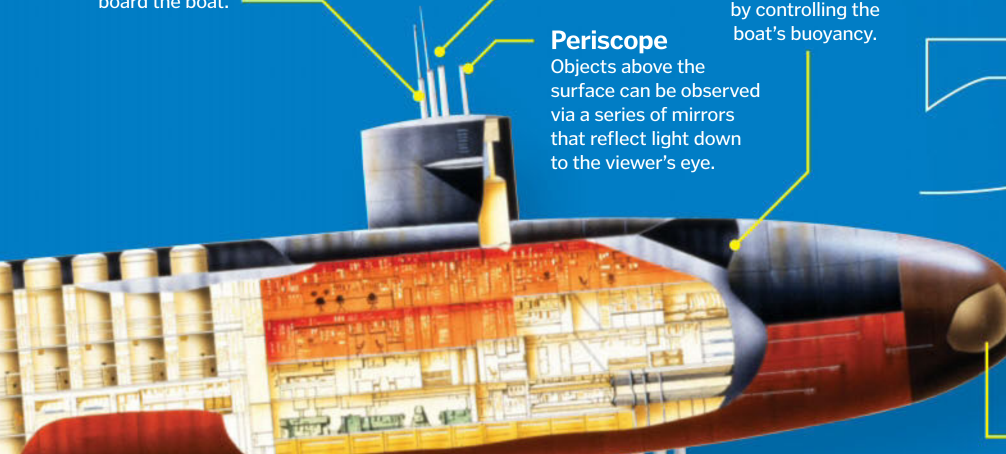
The sonar sphere emits pulses of sound waves that travel through the water.

Calculating distance

By measuring the time that it takes for the sound wave to get back to the sphere, the distance between the sub and the object can be calculated.

Bounce back

When the sound waves hit an object, they reflect back towards the sonar sphere.



Snorkel

When surfaced, air enters the sub through a snorkel, but when submerged, oxygen is generated on board the boat.

Antenna

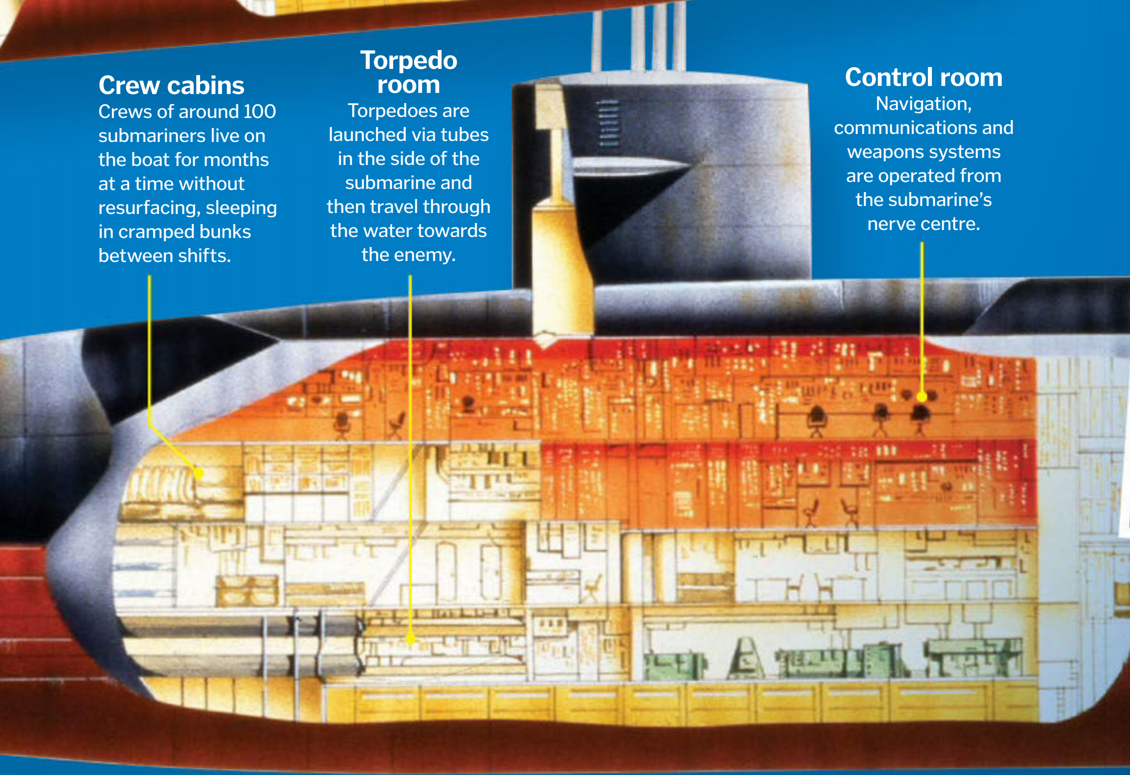
Underwater communications are carried out using low-frequency radio waves, which are able to penetrate the water.

Periscope

Objects above the surface can be observed via a series of mirrors that reflect light down to the viewer's eye.

Ballast tanks

This compartment is used as a ballast to provide stability for the submarine, and works by controlling the boat's buoyancy.



Crew cabins

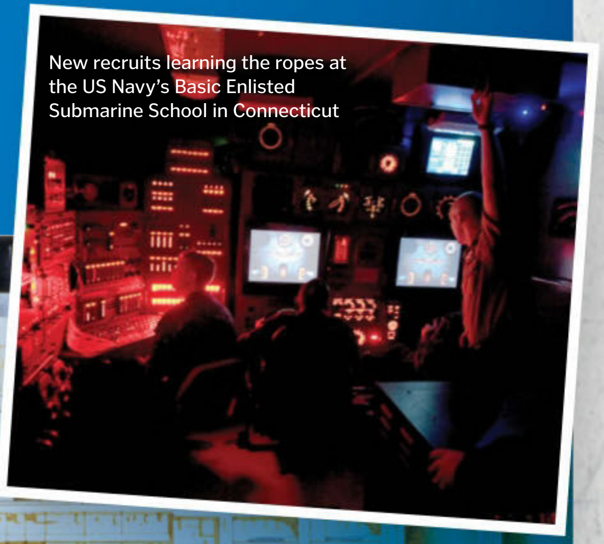
Crews of around 100 submariners live on the boat for months at a time without resurfacing, sleeping in cramped bunks between shifts.

Torpedo room

Torpedoes are launched via tubes in the side of the submarine and then travel through the water towards the enemy.

Control room

Navigation, communications and weapons systems are operated from the submarine's nerve centre.



New recruits learning the ropes at the US Navy's Basic Enlisted Submarine School in Connecticut

© Getty; WIKI; Dreamstime

SUPERSONIC SUBS

This underwater craft could circumnavigate the globe in just half a day

Moving at speed through water is very difficult, as liquid creates more drag than air. This means that you need a lot of energy to push through water at high speeds, and most modern submarines are only powerful enough to travel at around 75 kilometres per hour. However, researchers at the Harbin Institute of Technology in China are developing technology that could allow submarines to travel at the speed of sound, so around 5,400 kilometres per hour in seawater.

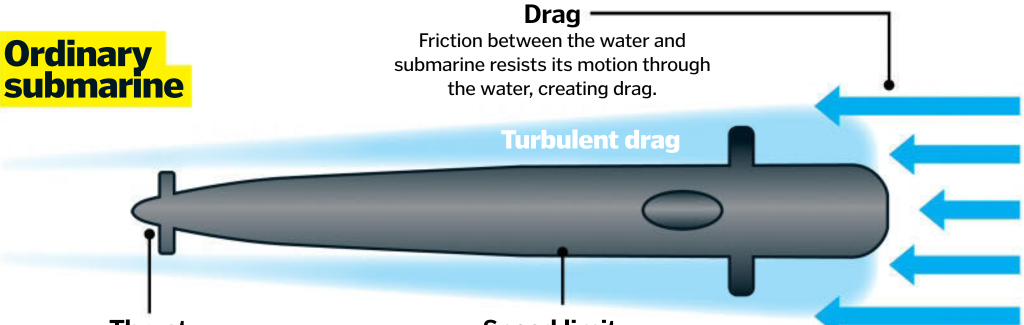
Their method is based on supercavitation, which was first developed by the Soviets in the 1960s to create high-speed torpedoes during the Cold War. It works by creating a supercavity of air around the vessel, reducing drag and allowing it to reach much faster speeds. The Soviets successfully achieved this with their Shkval torpedo, which could reach speeds up to 370 kilometres per hour, but it could only travel for a few kilometres, and couldn't be steered.

Steering is a problem because rudders, the typical method of navigation underwater, require water to create drag, and so will not work in a bubble of air. To overcome this, the Chinese scientists have created a liquid membrane that can be sprayed over the submarine, reducing drag on one side so that it can be steered in the other direction. So far, however, a method of underwater propulsion for long-range supersonic travel has yet to be developed, so their dreams of travelling from Shanghai to San Francisco in 100 minutes are still a long way off.

Speeding through the water

How would a supersonic submarine reach the speed of sound?

Ordinary submarine

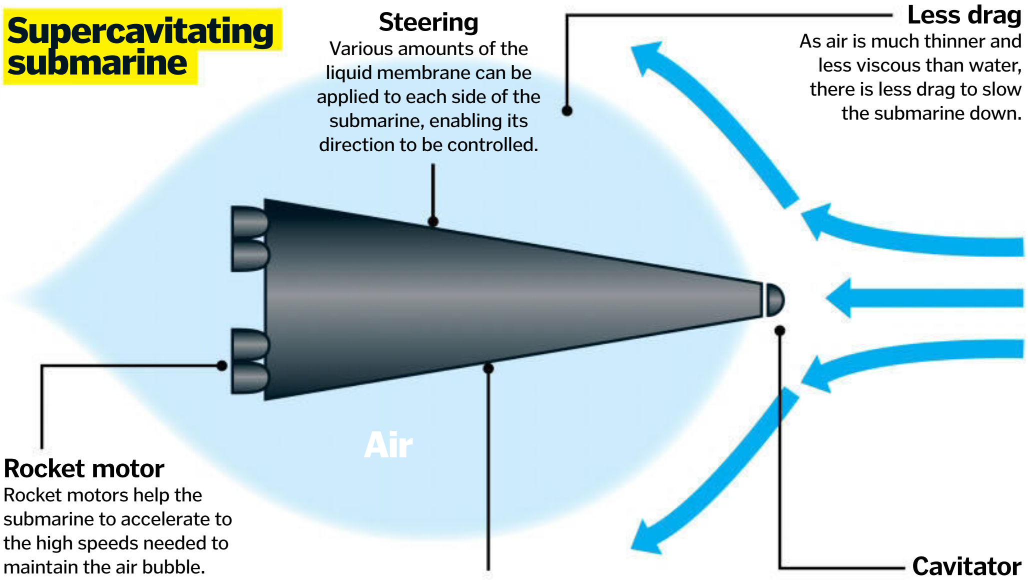


Drag
Friction between the water and submarine resists its motion through the water, creating drag.

Thrust
The submarine's propellers generate thrust, which pushes the submarine through the water.

Speed limit
To reach high velocity, lots of energy is needed to generate an amount of thrust much greater than the drag.

Supercavitating submarine



Steering
Various amounts of the liquid membrane can be applied to each side of the submarine, enabling its direction to be controlled.

Less drag
As air is much thinner and less viscous than water, there is less drag to slow the submarine down.

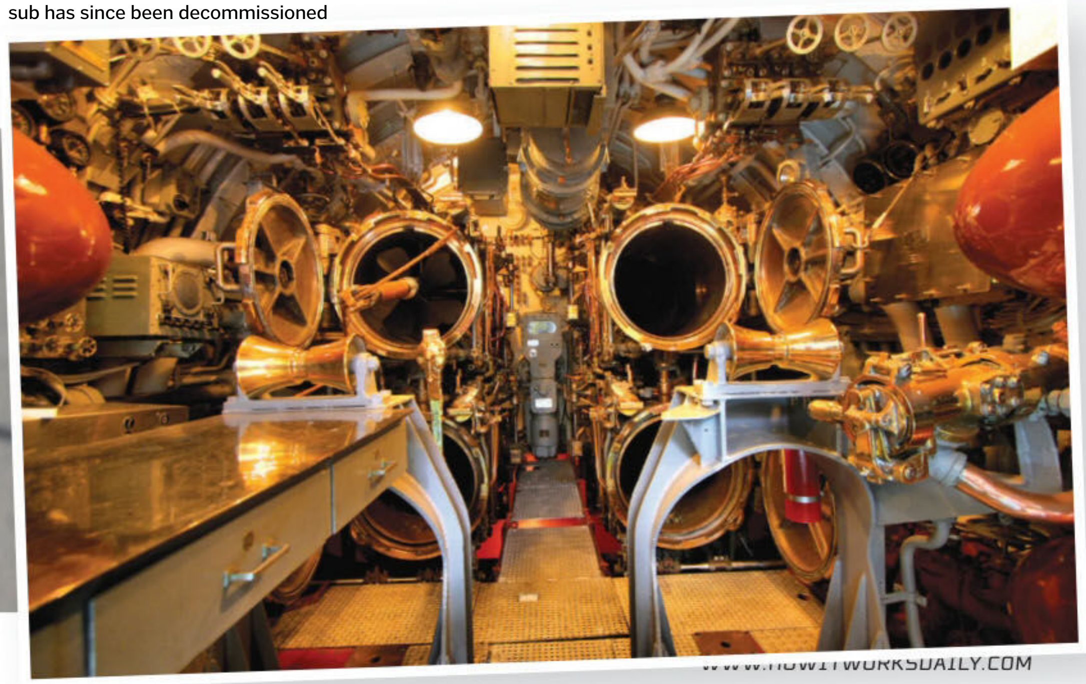
Rocket motor
Rocket motors help the submarine to accelerate to the high speeds needed to maintain the air bubble.

Liquid membrane
When first launched, a special liquid is sprayed over the submarine to reduce drag and get the vessel up to speed.

Cavitator
Once the submarine is travelling fast enough, the cavitator ejects gas from the nose with enough force to create a bubble around the vessel.

The cavitator of the Shkval torpedo

Inside the USS Bowfin torpedo room. This sub has since been decommissioned



DID YOU KNOW? *Russia's Typhoon class submarines are 175m long and weigh 48,000 tons, making them the largest in the world*

SUBMARINE DRONES

The autonomous underwater vehicles that render crews unnecessary

Keeping crews safe and alive at sea is a risky and costly business, so it's no wonder that the world's navies are already developing unmanned underwater vehicles (UUVs) to do the dangerous work for them. One particular area where these underwater drones are useful is mine hunting, as they can search for and even destroy underwater explosives while keeping the crews of nearby ships out of harm's way. The US Navy currently uses the Woods Hole Oceanographic Institution's (WHOI) Remote Environmental Monitoring UnitS (REMUS) vehicles for this very purpose, as each one is capable of doing the work of 12 human divers.

It's not just the military that these UUVs can help, as the ability to fit them with a variety of cameras and sensors also makes them useful for conducting scientific research. Underwater drones can survey and monitor places that are incredibly difficult for humans to reach, and gather information about marine wildlife in their natural environment. For example, WHOI's SharkCam drone has enabled scientists to observe the underwater hunting behaviour of great white sharks for the first time, showing that they use the darkness at great depths to avoid detection before ambushing their prey.

Ocean robots

Discover the important roles of unmanned vehicles

1

Sub hunting

The US Navy's Sea Hunter is the world's largest unmanned ship. It can sail on its own for up to three months at a time, using its short-range radar to detect diesel-electric submarines.

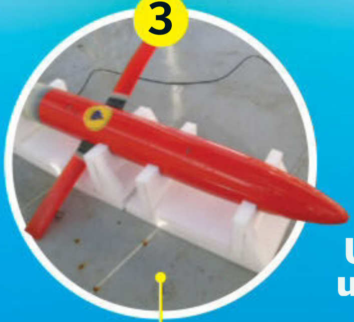
Unmanned surface vehicles

2

Deep diving

Built by Boeing, the ECHO Ranger can dive to depths of 3,000 metres, and was developed to capture high-res images of the ocean floor for the oil and gas industry. It is now also being used for underwater intelligence, surveillance and reconnaissance missions.

3



Long-distance gliding

WHOI's Spray Glider uses small changes in its buoyancy, combined with lift from its wings, to propel itself through the water. This means it uses little power, so can travel for 3,600 kilometres at a time, taking scientific measurements from its surroundings over long periods.

Unmanned underwater vehicles

4

Hull inspections

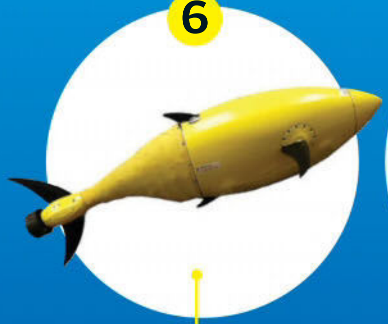
The US Navy's Hovering Autonomous Underwater Vehicle inspects the hulls of ships for explosive devices or damage. Data is gathered by the high-res imaging sonar, then sent to operators on board the ship in real time via a fibre-optic tether.

5

Cargo delivery

The dual-use Proteus submersible can operate autonomously or manned, as it can transport divers or deliver payloads over hundreds of kilometres without human intervention. There's space for up to six people inside, and it has a top speed of 18 kilometres per hour.

6



Harbour protection

Inspired by a tuna fish, the BIOSwimmer drone is being developed for the US Department of Homeland Security to patrol harbours and inspect ships. It has a flexible back section and fins to help it manoeuvre through the water, even in harsh environments.

7

Animal tracking

WHOI has outfitted one of its REMUS UUVs with instruments that enable it to locate, track and film marine animals. The SharkCam is pre-programmed to home in on a signal from a transponder beacon that is attached to an animal such as a great white shark.

Unmanned underwater vehicles

8

Amphibious missions

Capable of flying in the air and swimming underwater, the Naviator is the first amphibious drone. It has to stay tethered to its operator for continuous communications, but should help the military detect and map mines, and assist with search and rescue operations at sea.

9

Mine hunting

Designed to swim ahead of a ship, Saab's Double Eagle SAROV can detect, classify and dispose of mines in the vicinity. It can be remotely operated or function autonomously. Once a mine has been detected, it deploys a smaller mine sniper vehicle to destroy it.

© Dreamstime; WIKI

THE FUTURE OF SUBMARINES

What will underwater crafts look like in years to come?

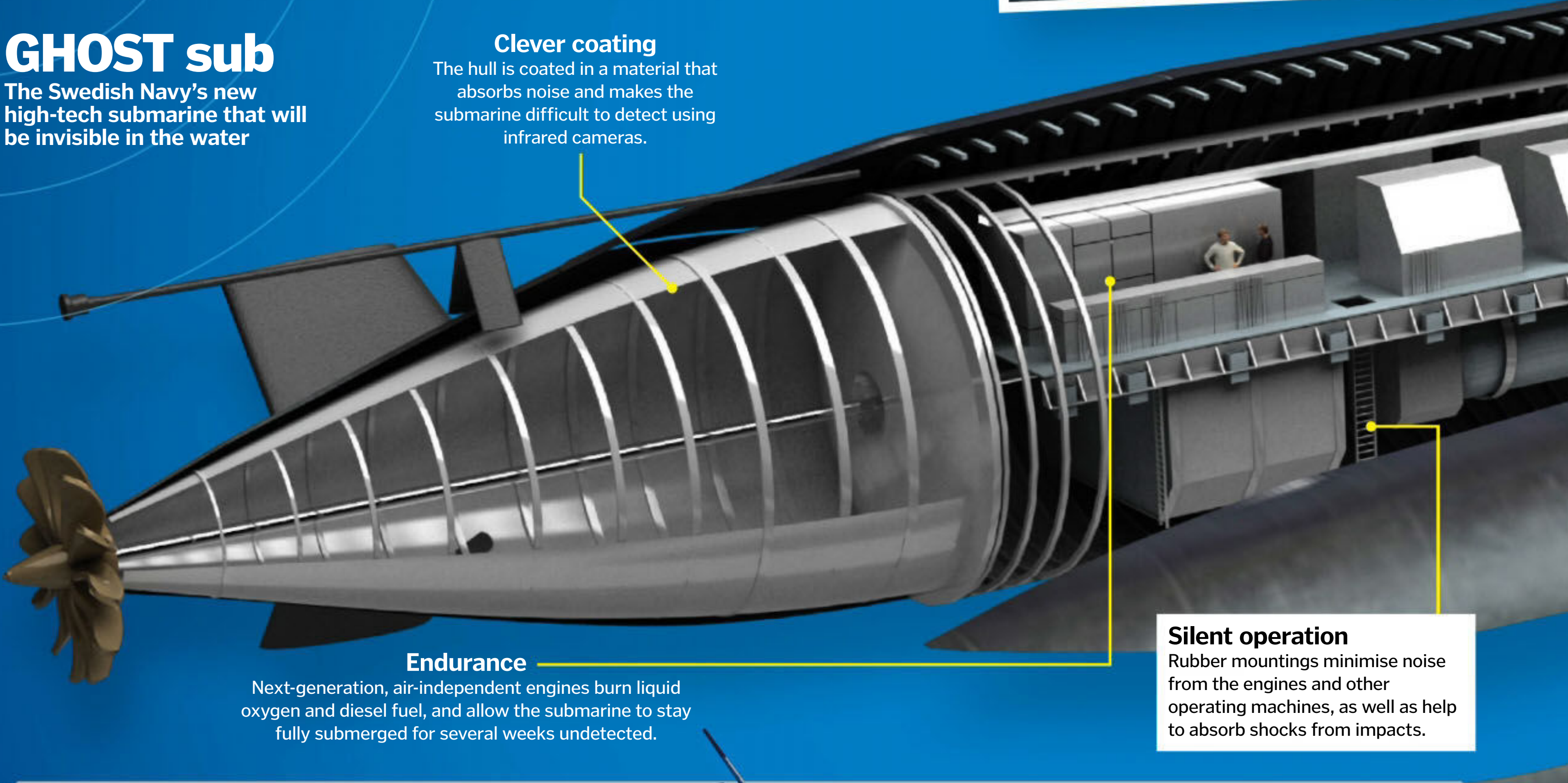
With technology advancing at speed, it will not be long before we find out whether the future of submarines is supersonic, unmanned or something else entirely. In fact, the latter is being explored by defence and security company Saab, and it is currently constructing two new super-stealthy Type A26 submarines for the Swedish Navy. With intelligence gathering and surveillance along coastlines becoming increasingly important, these high-tech submarines will be able to operate in shallow waters, and also feature Genuine HOlistic STealth (GHOST) technology, making them virtually silent and almost impossible to detect.

Per Neilson, program manager for the A26, says: "It will be much quieter, the sensors will be more advanced – detecting and documenting everything that goes on in the sea – and there will be a number of new capabilities such as the multi-mission portal in the bow that allows for the hosting of divers and small manned or unmanned vehicles. It will be a first-class intelligence-gathering platform." The A26 sub will dive to depths of 200 metres and carry a crew of 26. It is due to be completed by 2022.

The A26 submarine will be 62 metres long and weigh around 1,800 tons

GHOST sub

The Swedish Navy's new high-tech submarine that will be invisible in the water



Clever coating
The hull is coated in a material that absorbs noise and makes the submarine difficult to detect using infrared cameras.

Endurance
Next-generation, air-independent engines burn liquid oxygen and diesel fuel, and allow the submarine to stay fully submerged for several weeks undetected.

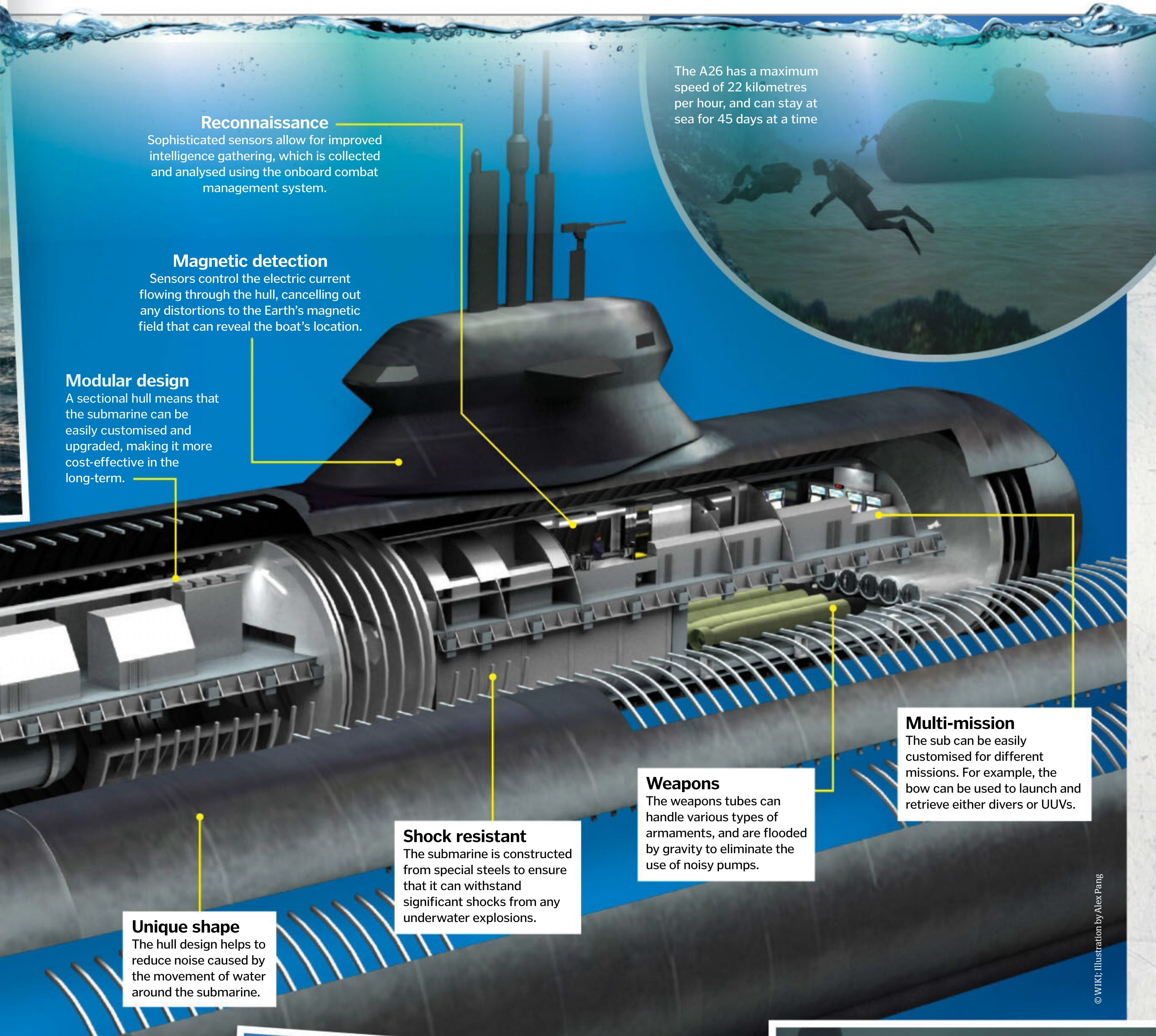
Silent operation
Rubber mountings minimise noise from the engines and other operating machines, as well as help to absorb shocks from impacts.

How you can explore the ocean

High-tech submarines aren't just reserved for the world's navies and scientists; DeepFlight has created a personal underwater craft that just about anyone can use to explore the oceans. The Super Falcon Mark II is an electric craft that can be operated with minimal training, and dives to a maximum depth of 120 metres. It can carry two people, a pilot and a passenger, and is small enough to fit on a standard yacht, so you can take it for a dive wherever you are in the world. The submarine is safe to use around marine wildlife, and if you do encounter any trouble, whether it's shark-related or not, it will automatically return to the surface.

The Super Falcon Mark II is the underwater equivalent of an airplane, able to fly through the ocean

DID YOU KNOW? *The longest submarine mission lasted 11 months, and the crew spent 4,700 hours underwater*



The A26 has a maximum speed of 22 kilometres per hour, and can stay at sea for 45 days at a time

Reconnaissance
Sophisticated sensors allow for improved intelligence gathering, which is collected and analysed using the onboard combat management system.

Magnetic detection
Sensors control the electric current flowing through the hull, cancelling out any distortions to the Earth's magnetic field that can reveal the boat's location.

Modular design
A sectional hull means that the submarine can be easily customised and upgraded, making it more cost-effective in the long-term.

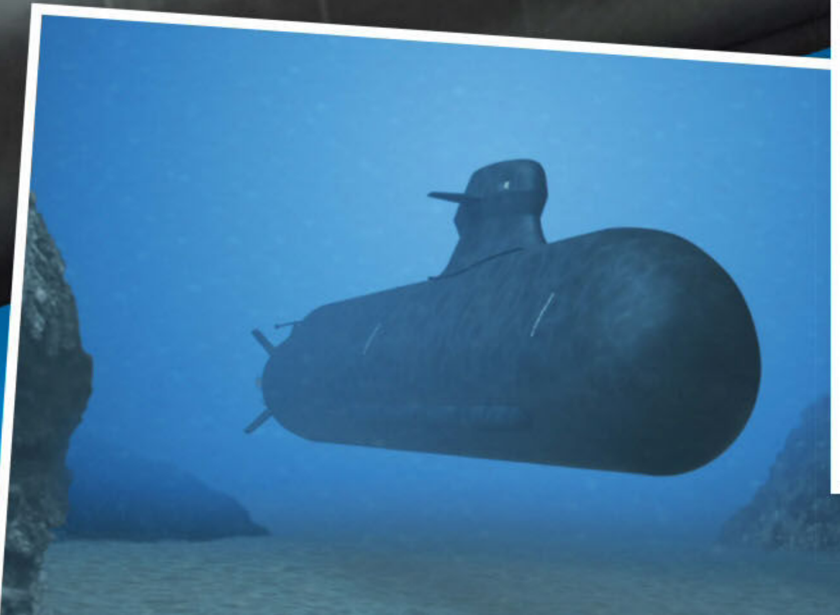
Multi-mission
The sub can be easily customised for different missions. For example, the bow can be used to launch and retrieve either divers or UUVs.

Weapons
The weapons tubes can handle various types of armaments, and are flooded by gravity to eliminate the use of noisy pumps.

Shock resistant
The submarine is constructed from special steels to ensure that it can withstand significant shocks from any underwater explosions.

Unique shape
The hull design helps to reduce noise caused by the movement of water around the submarine.

© WIKI; Illustration by Alex Pang



The A26 will be able to withstand temperatures down to -2˚C

Divers can be deployed from the sub's bow for stealth missions

Beach-cleaning machines

The best way to sort the litter from the sand

This raking beach cleaner quickly clears the sand of any rubbish

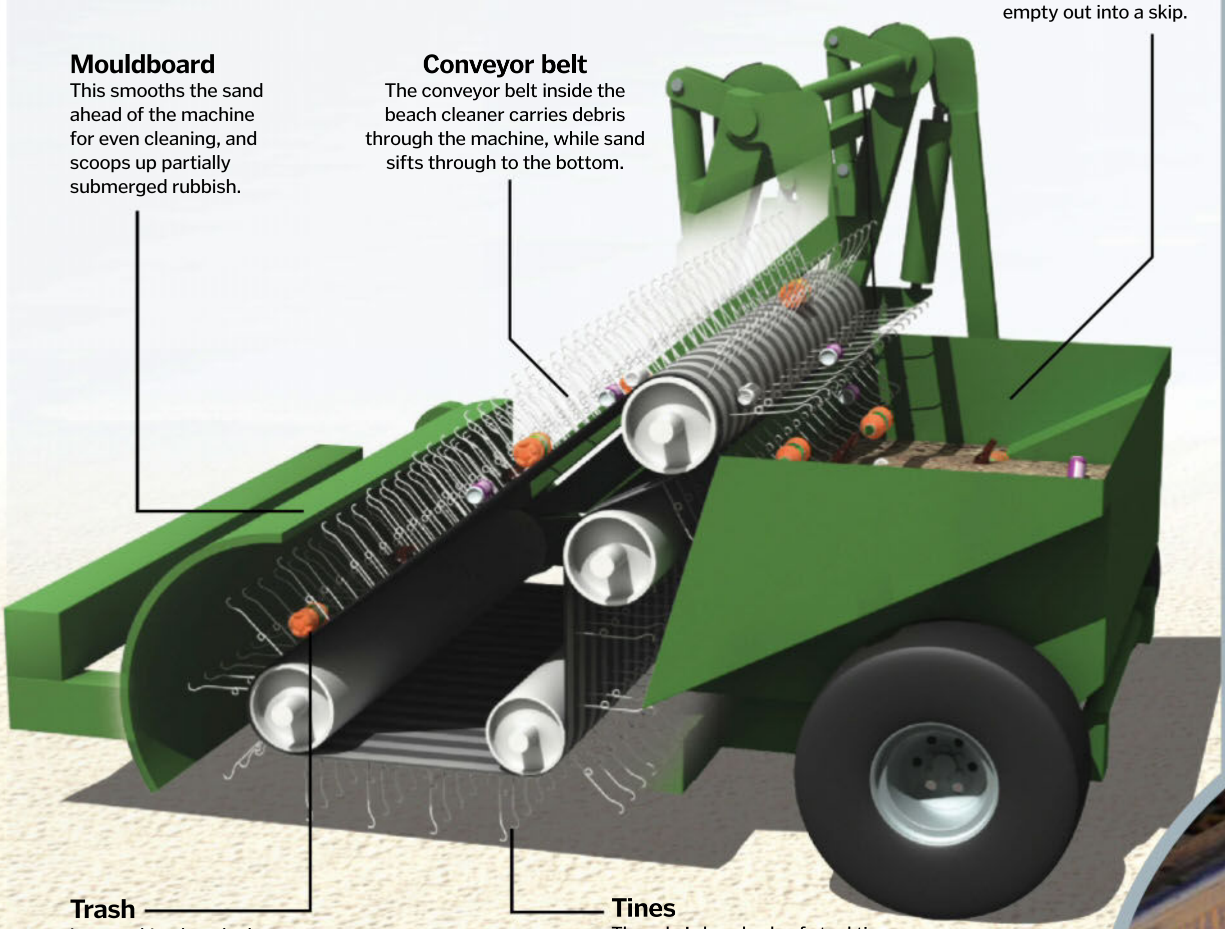
Nobody wants to relax or play on a polluted beach, so resorts and beach owners use beach-cleaning machines to keep them pristine. They're usually towed by tractors or quad bikes, although private beach owners often use smaller models that are pushed along.

Inside the machine is a mouldboard, which levels the sand to create an even surface to work on. Then, rows and rows of stainless-steel teeth rake the beach every second, scooping up refuse as small as a cigarette butt. The teeth travel around a conveyor-belt system and deposit the debris in a bucket – or hopper – for emptying later. Meanwhile, any residual sand escapes through the perforations in the conveyor, so it can fall back onto the beach.

Another type of beach cleaner, the sifter, works best for cleansing fine, dry sand of materials such as tar and oil. It passes everything through a series of filters, dropping the clean sand back onto the beach, ready for sunbathing and building sandcastles.

Raking it in

Beach-cleaning machines move at high speed to pick up waste and pollution, leaving only sand behind



Hopper
The hopper stores all of the collected waste. Once full, it lifts up to empty out into a skip.

Mouldboard
This smooths the sand ahead of the machine for even cleaning, and scoops up partially submerged rubbish.

Conveyor belt
The conveyor belt inside the beach cleaner carries debris through the machine, while sand sifts through to the bottom.

Trash
Large raking beach cleaners can pick up everything, from the tiniest shard of glass to a big beverage can.

Tines
The rake's hundreds of steel tines are offset to scoop every bit of debris into the machine.

Leaves on the line

Why this problem can cause chaos for train commuters

In the UK, a mature tree has between 10 and 50,000 leaves, poised to fall on railway tracks every autumn and cause delays and frustration for commuters. That's because when trains flatten the foliage, they leave behind a slimy muck, which is similar to Teflon – the non-stick coating on saucepans. To avoid wheelspin, train drivers have to brake early and accelerate gently, and this safety precaution leads to delays.

To help combat this problem, modern trains are fitted with wheel slip protection, which operates just like automatic braking systems on road vehicles. The system monitors the rotation of each axle, and if one happens to be spinning faster than the other, the brake is released until the speed equalises, then the brake is reapplied.

Trains can also spray ultra-fine sand ahead of the wheels to help aid traction, or a fleet of Railhead Treatment Trains can do the same thing on a larger scale. They spray high-powered jets of water along the tracks to clear them, then apply an adhesive paste – a mixture of sand and aluminium called 'sandite' – on the lines to improve grip. Typically, these trains run during off-peak hours to get the tracks cleared for the busiest commuting times.

Leaves on the line can look lovely, but could make you late

©Thinkstock; Illustration by Adrian Mann

FESTIVAL OF ARCHAEOLOGY 2016

More than 1,000 events across the UK.

Saturday 16 to Sunday 31 July.

A huge range of events & activities to inspire all ages.

Council for British Archaeology

Historic England

Cadw

Llywodraeth Cymru
Welsh Government

Find an event near you: **archaeologyfestival.org.uk**

Coordinated by the Council for British Archaeology – a charity working to protect and promote archaeology, to enrich people's lives now and in the future.
To find out more about our work please visit **www.archaeologyuk.org**

TRANSFORM YOUR CD AND DVD COLLECTION...

FROM THIS

Maximise CD Life and keep 5 times more in the same space!

ONE BINDER STORES UP TO 120 DISCS

TO THIS

Stunning Limited Offer

£22.95*

Normally ~~£42.09~~

Quote promotional code **HW0716** on your basket page

Burgundy Leather CD/DVD Organiser Ref: **K-469**

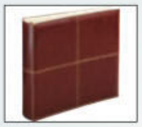
THE ULTIMATE LEATHER CD/DVD ORGANISER!

- **FIND** your favourite Music, Film, Photo, Data disc in seconds
- **PROTECT** your discs from dust, dirt, light and scratches
- **MATCH** your CD/DVD/Blu-Rays with their booklet covers
- **PREVENT** 'CD-Rot' from corrupting your music collection

arrowfile
The Collectable Storage Specialists
The Professionals Choice
Photos, Memorabilia & Collectables

Extra refill sleeve pages RJ0CD44 (pk of 10) £9.95 | Additional Album PLUS FREE Slipcase K-470 £22.95 | Each album will hold up to 60 CDs with 60 covers or 120 CDs without covers | Album Size: 292mm x 337mm x 75mm. Total Album Capacity: 15 Sleeve Pages. | *Plus Standard UK delivery £5.95 | One album or double album set offer per household (see website for details)

This Amazing Offer Includes:

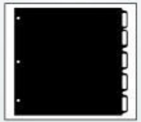


Binder Album
£22.95

10 Black Refill Pages ~~£9.95~~

Music Labels ~~£2.99~~

Pack of CD Index Sheets and Dividers ~~£5.70~~



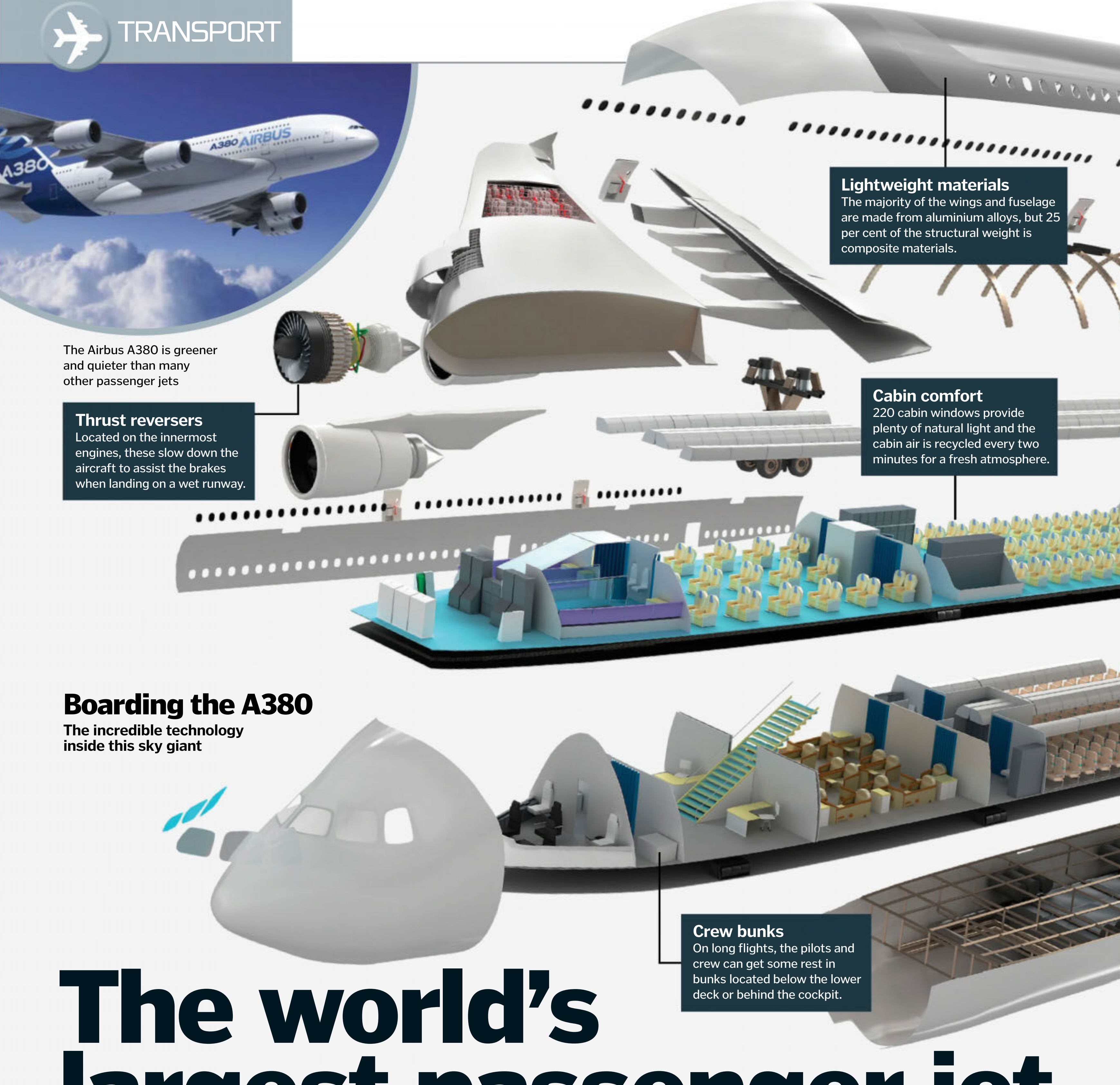
Page Numbers ~~£0.50~~

GO TO OUR WEBSITE FOR ALL YOUR COLLECTABLE ARCHIVAL STORAGE REQUIREMENTS
Family History, Postcards, Stamps, Coins & Medals, Display Presentation Cases & Cabinets, Photo Slip-in & Traditional Albums, Oversized & Scrapbooking Binders, Portfolios, Photographic & CD/DVD Accecssories...

SHOP ONLINE - WWW.ARROWFILE.COM | ORDER HOTLINE - 0844 855 2060

*Quote promotional code: HW0716

Flash Foto Ltd T/A Arrowfile, 147 Churchill House, Stirling Way, WD6 2HP Reg No. 1561035



The Airbus A380 is greener and quieter than many other passenger jets

Lightweight materials
The majority of the wings and fuselage are made from aluminium alloys, but 25 per cent of the structural weight is composite materials.

Thrust reversers
Located on the innermost engines, these slow down the aircraft to assist the brakes when landing on a wet runway.

Cabin comfort
220 cabin windows provide plenty of natural light and the cabin air is recycled every two minutes for a fresh atmosphere.

Crew bunks
On long flights, the pilots and crew can get some rest in bunks located below the lower deck or behind the cockpit.

Boarding the A380

The incredible technology inside this sky giant

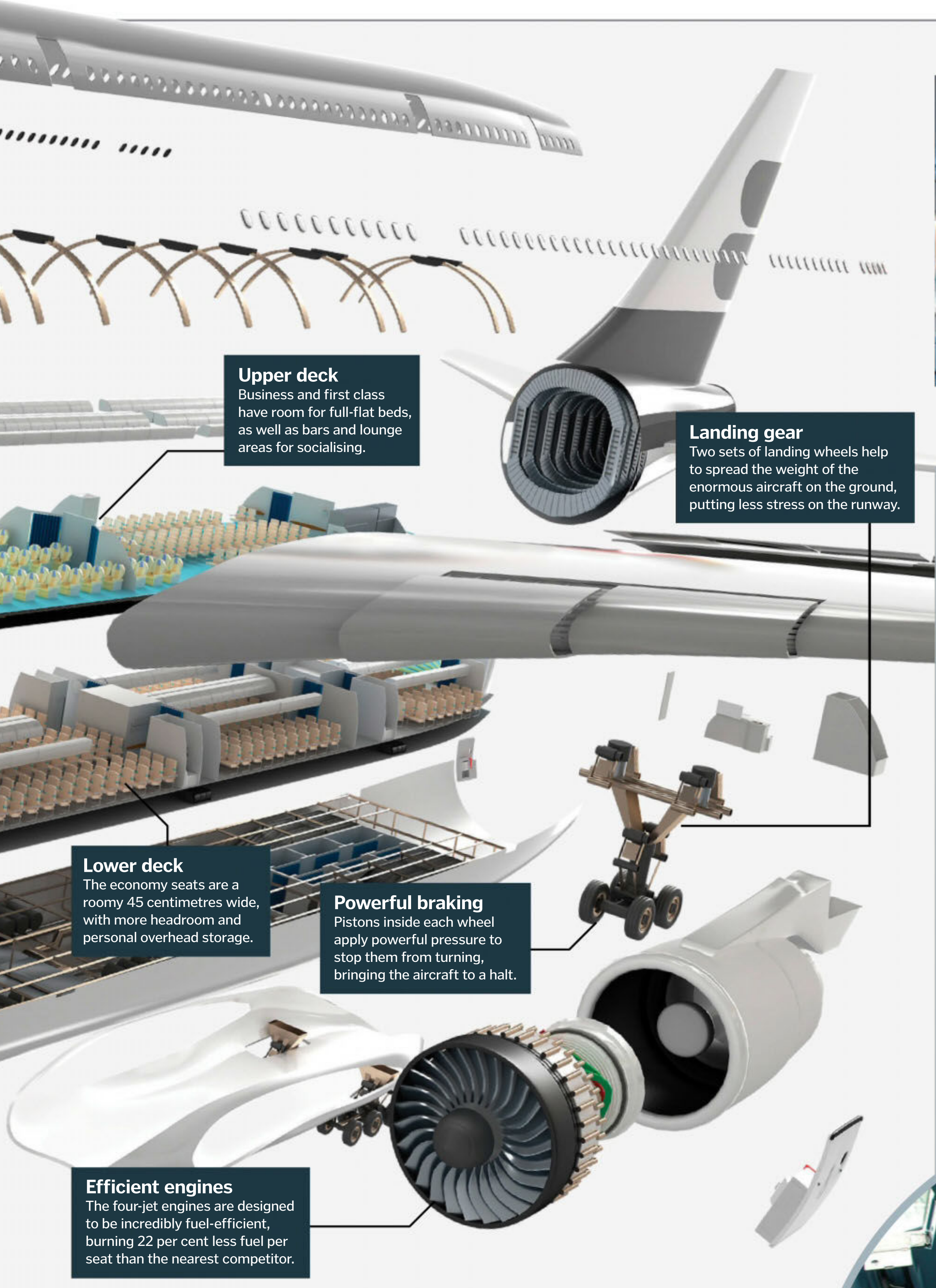
The world's largest passenger jet

How does the enormous double-decker Airbus A380 get off the ground?

Ferrying travellers all over the globe is an expensive business for the world's airlines, so it makes sense that they would want to pack as many passengers as possible onto each aircraft, reducing the number of flights they need to make. Thanks to its double-decker design, the Airbus A380 is capable of carrying up to 853 passengers at a time, if it is in a single-class cabin configuration. That's over 150 more than the aircraft's competitor, the Boeing 747-8. Most A380s, however, feature four separate classes, with economy and premium economy on the lower deck of the airplane and the more spacious business and first class upstairs, which reduces the passenger number to 544. This is still a 40 per cent increase on the 747-8's four-class capacity.

As well as being the largest passenger jet, the A380 is one of the quietest, with dampeners reducing engine noise to half that of other jets. It is also more environmentally friendly, because it needs to take fewer flights to deliver the same amount of passengers, and the fuel-efficient engines are claimed to give off 22 per cent fewer CO_2 emissions than the jet's closest competitor.

DID YOU KNOW? *The Airbus A380 is covered in three layers of paint weighing around 500 kilograms*



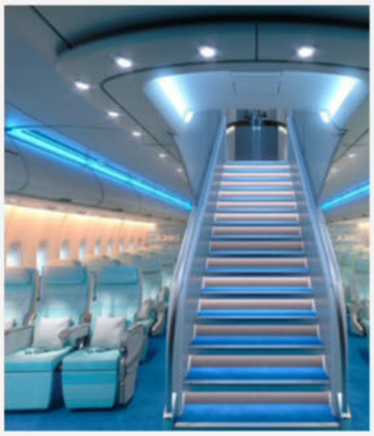
Upper deck
Business and first class have room for full-flat beds, as well as bars and lounge areas for socialising.

Landing gear
Two sets of landing wheels help to spread the weight of the enormous aircraft on the ground, putting less stress on the runway.

Lower deck
The economy seats are a roomy 45 centimetres wide, with more headroom and personal overhead storage.

Powerful braking
Pistons inside each wheel apply powerful pressure to stop them from turning, bringing the aircraft to a halt.

Efficient engines
The four-jet engines are designed to be incredibly fuel-efficient, burning 22 per cent less fuel per seat than the nearest competitor.



Two staircases provide access to the aircraft's upper and lower decks

Next-gen flight deck

The cockpit of the A380 is designed to be very similar to that of other Airbus aircraft, minimising the amount of time that pilots have to spend training to fly it. It features an instrument panel with eight large, interactive liquid crystal display units showing navigation, engine and systems information, as well as a transparent head-up display that superimposes information over the pilot's view. An electronic library also replaces the traditional paper documentation used by pilots, allowing them to locate operational information more easily and analyse the aircraft's performance. As the plane prepares for landing, the process is made easier as the flight crew can pre-select the optimum runway exit at their destination airport, and leave the autopilot to regulate deceleration after touchdown accordingly. This helps to reduce runway occupancy time and therefore increase the number of aircraft the airport can handle at any given time.

The A380's cockpit is designed to make Airbus pilots feel at home

© Airbus; Getty

Building an aircraft of this enormous size does present a few problems, though. Many airlines have had to modify their aircraft hangers to accommodate the increased height and wingspan of the A380, and some airports just don't have enough space for them to park. Also, to speed up the process of boarding and offloading such a large number of passengers, two gangways from the aircraft to the terminal building are needed – a set-up that only certain airports are capable of.

As a result, the A380 can usually be found travelling to and from the world's biggest international airports, making the most of its 15,200-kilometre range to deliver passengers to far-flung destinations in style.

DAY IN THE LIFE OF

An Underground driver

Do you have what it takes to drive London's tube trains?

Travelling up and down London Underground lines might look pretty straightforward, but the job of a tube driver is very mentally demanding. Although the trains are mostly automated, drivers must still remain fully alert throughout their shift, which can last between five and eight hours. It's their responsibility to ensure passengers get on and off safely at each stop, and deal with any faults or emergencies that may arise. Before they climb into a cab, every driver must pass tests of their reaction speeds and problem-solving skills, and learn the many rules, regulations and procedures of the Underground.

BE PREPARED
3:15am

Before leaving the house for work, drivers must ensure they have comfortable footwear and high-visibility clothing in case they need to walk on the tracks, a radio for communicating with the control room, and a lamp in case they get stuck in the dark tunnels. They may also pack food and water, as there's always a chance they could get stuck on the line.

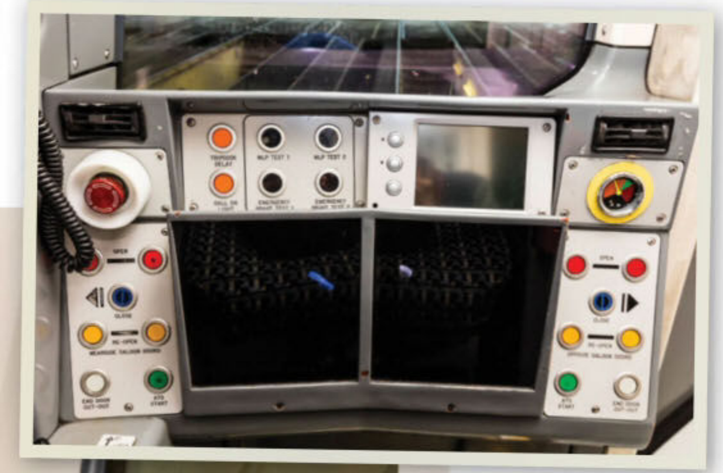
BOOK ON
4:45am

When they arrive at the train depot, the driver must sign in to confirm that they are fit to work, and get approval from a manager too. They then check the notices in order to see if there are any faults or disruptions on the line, and look up exactly where their train is in the depot.

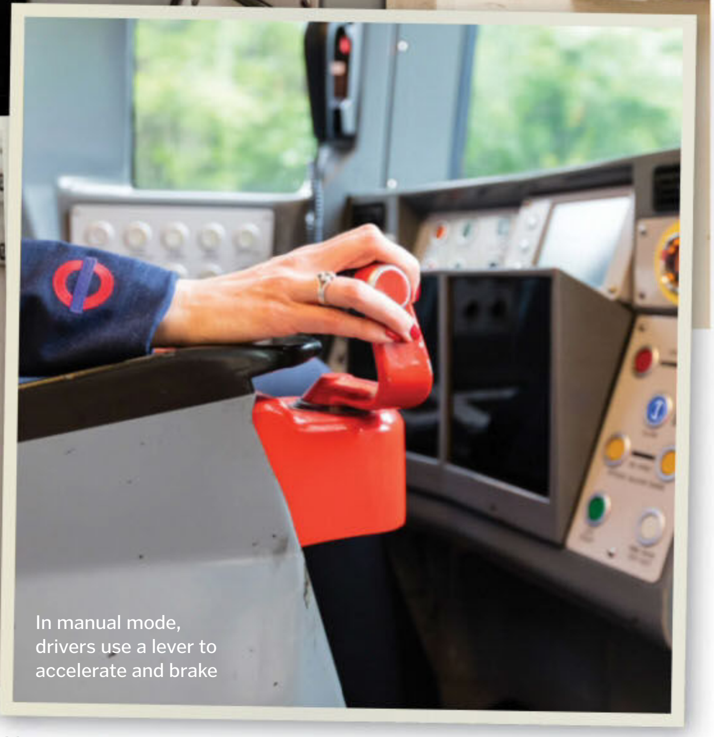
PUSH TO START
5:08am

Once on the train, the driver completes a series of system checks to ensure it is working properly, then pushes a lever to get it moving. The further forward they push the lever, the faster the train goes. Speed limits range from 16 to 80 kilometres per hour along

Tube drivers must remain vigilant at all times, looking out for any hazards



In automatic mode, the driver simply pushes buttons to start and stop



In manual mode, drivers use a lever to accelerate and brake

the lines, and they must hit certain speed targets to adhere to the train timetable.

GO AUTOMATIC
5:17am

The tube trains also feature an automatic mode, which simply requires the driver to push a single button to start the train. Wires in the track, which come from the central control room, send information to the train about how fast it should go and when it should stop, so it can keep to the timetable by itself.

AT THE STATION
5:27am

Once the train has come to a stop, a signal in the cab tells the driver it is safe to open the doors. A countdown then starts on their display, showing them how long they have before they need to get moving again. They closely monitor CCTV footage of the platform, and once they can see that everyone is safely on board, they close the doors.

READING THE SIGNALS
5:30am

If the train up ahead is running late, then a red signal will show on the cab display, informing the driver that it is not safe to proceed. Once the track is clear, they can push the button to go again. In places where the track divides, they must know which route to take and constantly be on the lookout for any hazards.

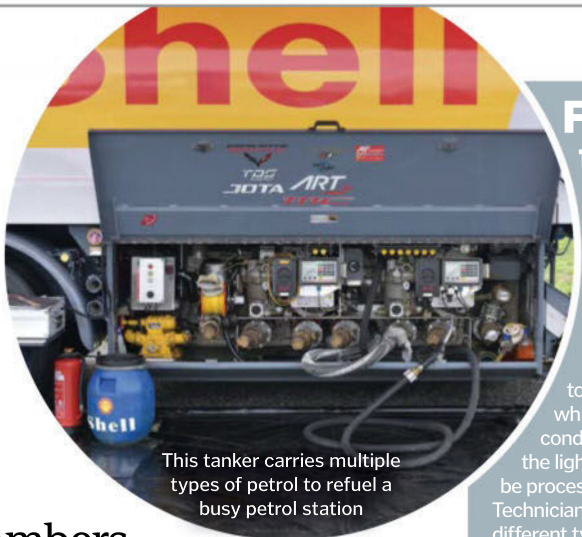
IN CASE OF EMERGENCY
7am

Drivers are able to fix most train faults themselves, but if a serious fault occurs, they will proceed to the next station so the passengers can evacuate. If the train gets stuck in a tunnel, the driver can rub together the wires running along the tunnel wall, which causes the electrical current flowing through the track to short circuit and turn off, enabling the passengers to safely walk to the next station.

HANDING OVER
8am

Tube drivers cannot drive for more than four hours and 15 minutes without a break. Before leaving the train, they shut it down and inform the next driver of any faults that have arisen during their shift. If it's the end of the day, the driver must check that all of the passengers have vacated, and drive the train back to the depot.

Refilling service stations


This tanker carries multiple types of petrol to refuel a busy petrol station

Under the forecourt lie vast chambers filled with fuel. Here's how it gets there

When your vehicle runs out of fuel, you fill up the tank at a service station. But what do the stations do when they're running on empty? It all begins at the oil refinery, where petrol and diesel are produced. These products travel along pipes to terminals, where fuel tanker trucks load up and distribute it to service stations all over the country.

To refill a service station, the truck driver removes the manhole cover that conceals the vast underground storage units (USTs) where these flammable, dangerous liquids are kept. A station might have as many as five USTs – holding up to 75,000 litres each – and these are joined to the inlet pipe to which tankers connect.

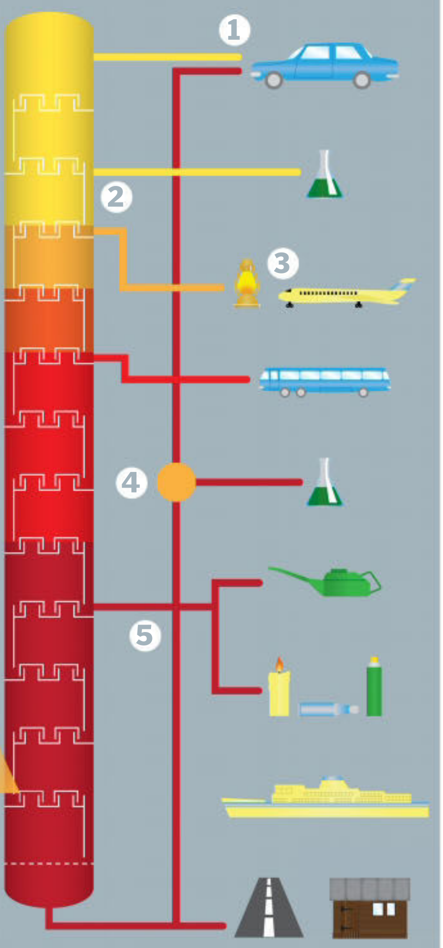
After removing the covers, the driver uses a metal pole called a dipstick to check fuel levels in each unit. Then he attaches two hoses: one to vent fuel vapour and one to dispense fuel from the truck to the unit, and monitors the valves and gauges on the tank until the units are full. After disconnecting the hoses, he uses the dipstick again to check levels before replacing the covers.

USTs are equipped with systems that automatically monitor the volume of fuel they contain. Changes in temperature can alter the amount, and some petrol is lost through the release of vapours as we pump it into our cars. Station operators combine this data with sales projections to work out when it's time for a refill.

From crude oil to petrol

Crude oil is changed into petrol and other products at a refinery. The oil is pumped through a distillation tower, where hot furnaces break it down into vapours and liquids. This separates components of the oil into 'fractions', according to their weights and boiling points.

Lighter fractions rise to the top of the tower before they condense into liquids, while heavier – and less profitable – fractions condense towards the bottom. Petrol is one of the lighter fractions, but heavy fractions can also be processed into petrol to increase the yield. Technicians blend various fractions to make the different types of fuels. These products are then stored in tank farms near the refinery, and carried in pipelines to additional tanks.



1 Petrol Petrol is a blend of light hydrocarbons, and can also be produced by 'cracking' heavier fractions or 'reforming' naphtha.

2 Kerosene Slightly heavier fractions are converted into kerosene and other petroleum products, such as heating oil.

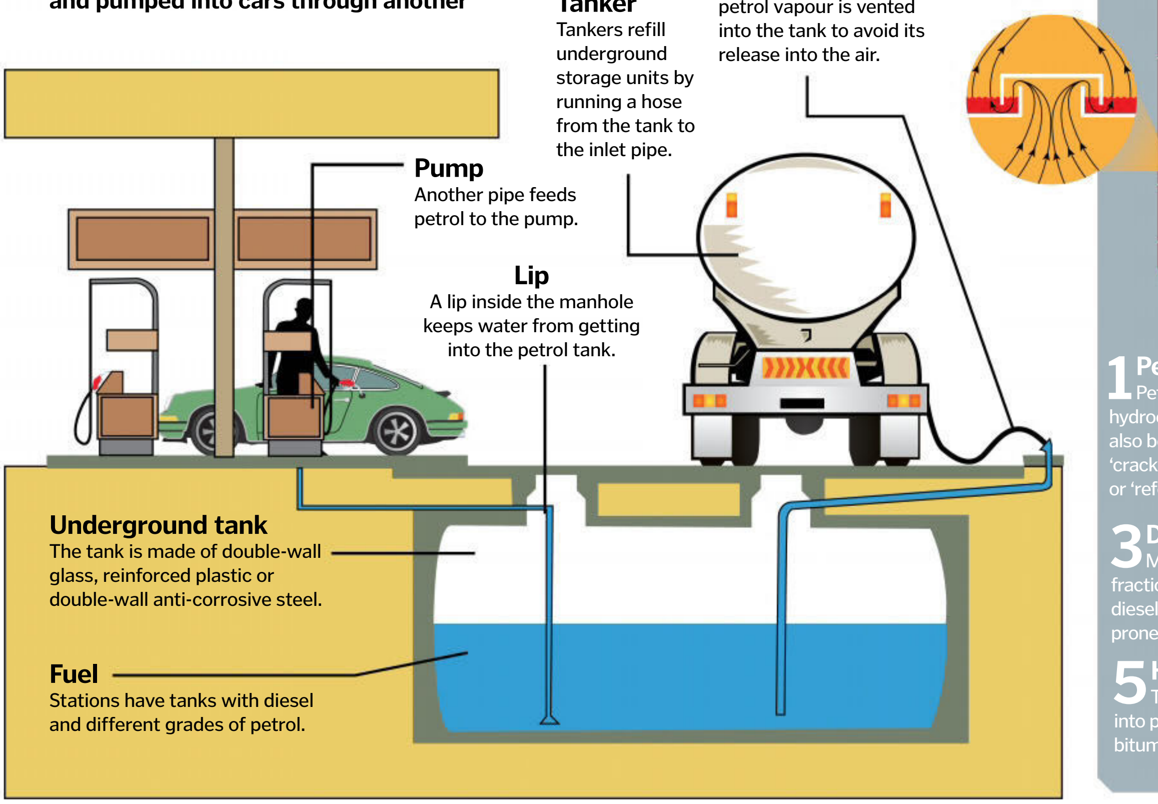
3 Diesel oil Middleweight fractions are refined into diesel fuels, which are less prone to explosion.

4 Cracking Heavier fractions are converted into chemicals, lubricating oil, and petrol through cracking.

5 Heavy fractions The heaviest fractions not reformed into petrol become industrial fuel and bitumen, a material used in roofing.

Underground storage tanks

Petrol is refilled by tankers through one pipe and pumped into cars through another



Tanker
Tankers refill underground storage units by running a hose from the tank to the inlet pipe.

Vent and inlet pipe
While the units are refilled, petrol vapour is vented into the tank to avoid its release into the air.

Pump
Another pipe feeds petrol to the pump.

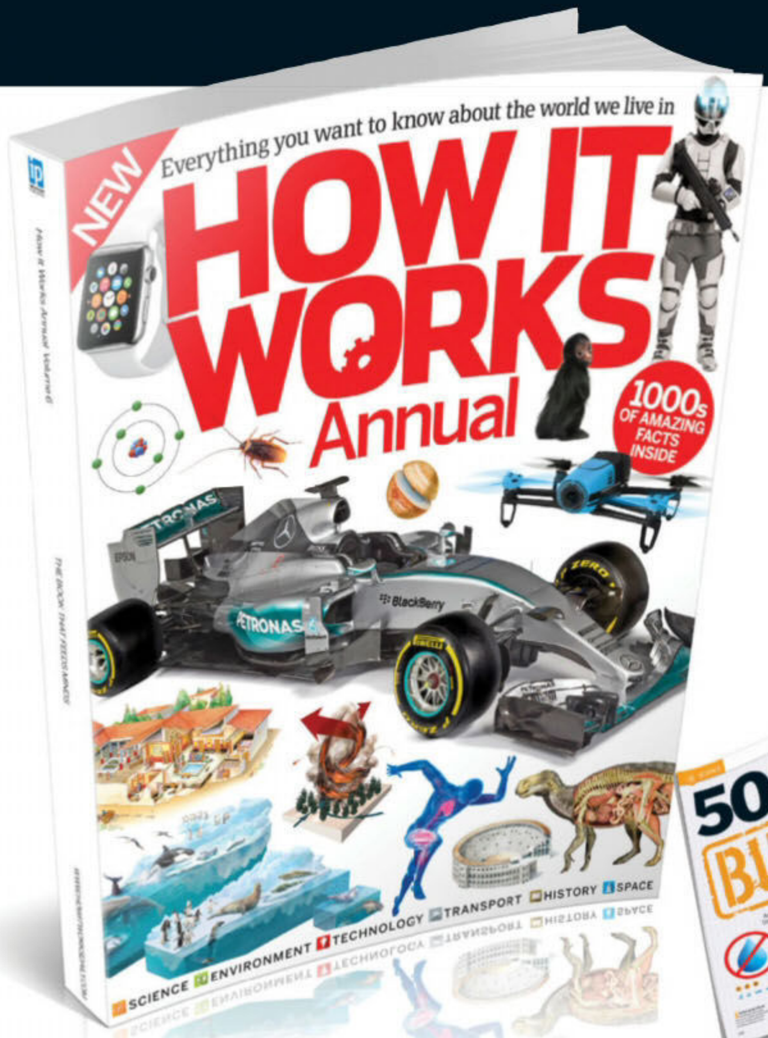
Lip
A lip inside the manhole keeps water from getting into the petrol tank.

Underground tank
The tank is made of double-wall glass, reinforced plastic or double-wall anti-corrosive steel.

Fuel
Stations have tanks with diesel and different grades of petrol.

© Getty

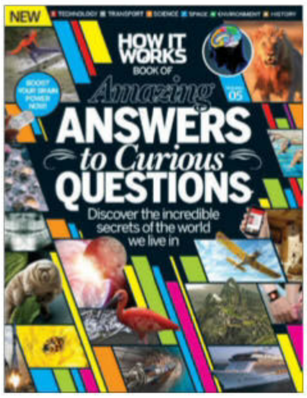
From the makers of HOW IT WORKS


NEW
Everything you want to know about the world we live in
HOW IT WORKS Annual
1000s OF AMAZING FACTS INSIDE
SCIENCE
ENVIRONMENT
TECHNOLOGY
TRANSPORT
HISTORY
SPACE

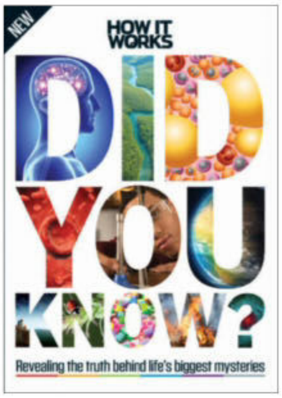
HOW IT WORKS Annual

From the science behind love, to the latest technology trends, the How It Works Annual is a collection of the best content from the last year including over 1,000 facts about everything from ice skating to the life of a dinosaur.

Also available…


NEW
HOW IT WORKS BOOK OF
Amazing ANSWERS to Curious QUESTIONS
Discover the incredible secrets of the world we live in

EVERYTHING YOU NEED FOR ALL QUADCOPTERS, DRONES AND UAVS
NEW
DRONES
TOP 10 DRONES
KNOW THE LAW
AMAZING WAYS DRONES ARE BEING USED TODAY!
HACK YOUR DRONE
5 COOL THINGS TO DO WITH YOUR DRONE
HOW TO BUILD YOUR OWN



A world of content at your fingertips

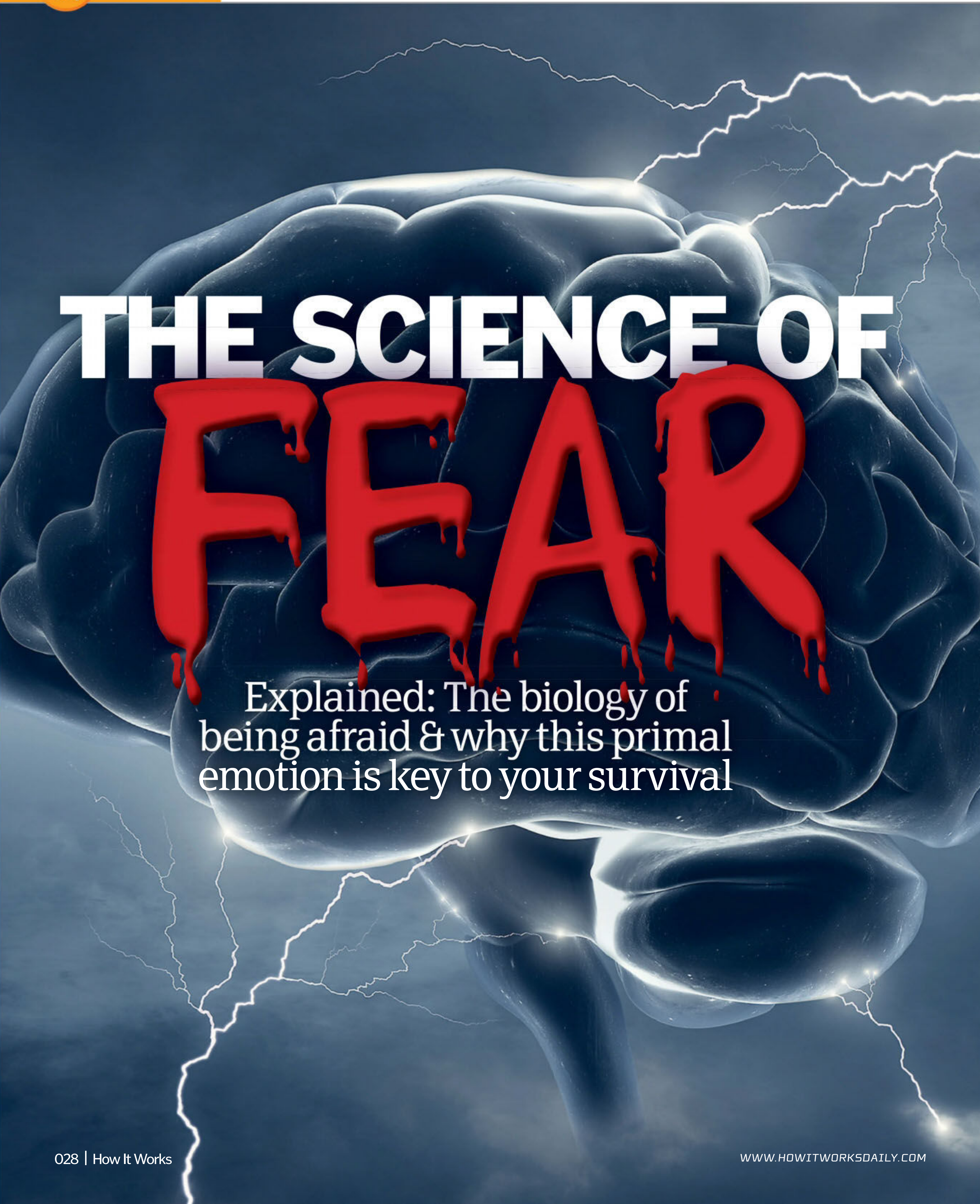
Whether you love gaming, history, animals, photography, Photoshop, sci-fi or anything in between, every magazine and bookazine from Imagine Publishing is packed with expert advice and fascinating facts.

BUY YOUR COPY TODAY

Print edition available at www.imagineshop.co.uk

Digital edition available at www.greatdigitalmags.com

Print
Tablet
Phone
Desktop



THE SCIENCE OF FEAR

Explained: The biology of being afraid & why this primal emotion is key to your survival

DID YOU KNOW? *Studies show that we identify images of snakes and spiders more quickly than non-threatening pictures*

Home alone at night, you hear a loud crash. In an instant your heart starts racing, your muscles tense and your breath quickens. You are immediately alert, primed to fight or flee the source of the sound, which turns out to be a pile of books falling off that shelf you've been meaning to fix. But in that moment, your brain and body reacted as if you were in mortal danger.

Fear is one of our strongest and most primal emotions. It's a big bad world out there, and being afraid of certain things protects us from potential danger to make sure we survive. Some evolutionary fears are hard-wired into our brains, but we can also develop new fears throughout our lives. As children we pick up on what makes our parents anxious, and we may also learn to fear certain things after negative experiences. Despite this, most of us are able to ignore our fears when it's clear we aren't in any immediate danger. We can enjoy the view from the top of a skyscraper rather than worry about falling, or turn out the lights safe in the knowledge that a predator won't devour us in the night.

However, people with phobias have an excessive fear response that causes both physical and psychological distress. These extreme fears are divided into three different groups: agoraphobia, social phobia and specific phobias. Agoraphobia is generally referred to as the fear of open spaces, but it applies to the dread of any situation that is difficult– to escape from, or where help would not be available if something went wrong. Social phobia is the intense fear of interacting with people or performing, while specific phobias are the fear of a particular situation, activity or thing.

These irrational fears can cause major disruptions to everyday life; somebody with acrophobia – an extreme fear of heights – may experience a panic attack simply trying to walk across a bridge. Depending on the trigger of their phobia, sufferers often go to great lengths to avoid situations that could affect them.

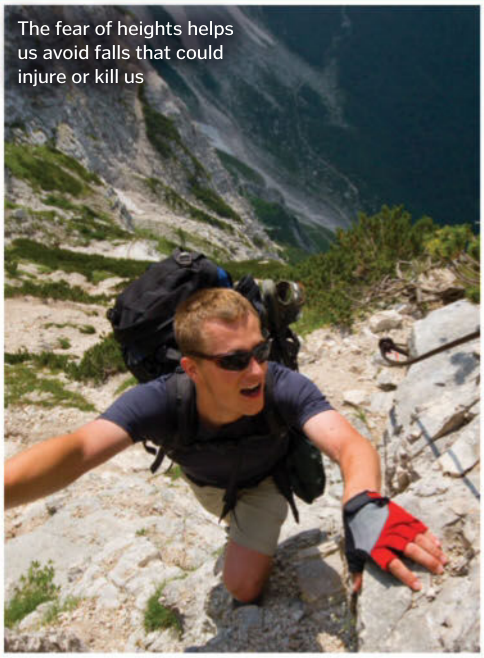
The cause of phobias is not always clear, but many cases are linked to experiencing or witnessing a traumatic event. For example, somebody may develop cynophobia – the fear of dogs – after being bitten. But whether the trigger is rational or irrational, as soon as the brain registers a scary stimulus, it activates the fight-or-flight response, thus preparing the body for action.

Natural fears

Some of our fears have developed as an evolutionary response to danger

> *"Even today, the majority of African lion attacks on humans occur after dark"*

We are more afraid of what hides in the dark, rather than the darkness itself



The fear of heights helps us avoid falls that could injure or kill us

Although most snake and spider species aren't poisonous to us, we are innately cautious around them

Darkness

Sight is arguably our most important sense. When we are faced with pitch-darkness we are left vulnerable, unaware of what is around us. At night, our early ancestors were at risk of being attacked by nocturnal predators. A study from 2011 found that even today, the majority of African lion attacks on humans occur after dark, and are more likely when the Moon is below the horizon. Although being hunted while we sleep isn't a risk for most of us, we are instinctively more anxious when unable to see.

Heights

A fear of heights is necessary to our survival, ensuring we are cautious in situations where we might injure ourselves. To study this, researchers set up a platform surrounded by a transparent material, giving the illusion of a cliff, and put young children on the platform to test their reaction. They found that most infants didn't try to move onto the transparent section, suggesting that they inherently avoided risking a drop. As our ancestors explored the world, this fear ensured they were wary of climbing to dangerous heights.

Poisonous creatures

While we may not be terrified of them from birth, evidence suggests that we are predisposed to detect and recognise spiders and snakes quicker than non-threatening animals. One theory is that our early mammal ancestors, evolving in a world dominated by reptiles, needed to identify and react to snakes to avoid becoming dinner. Another hypothesis is that our ancestors evolving in Africa coexisted with a number of poisonous spider species for millions of years, so being able to spot and avoid them was a vital skill.

©Thinkstock

Fight or flight

How your brain and body trigger this evolutionary survival instinct

A fear of flying is relatively common, and may have roots in the evolutionary fear of heights

Under normal circumstances, sensory information from your body is sent to the thalamus in the brain. The thalamus relays these signals to the cortex and the hippocampus for further processing, to provide a better understanding of what you're experiencing and put it into context. This analysis is forwarded to the amygdala, which triggers an appropriate emotional reaction to the situation.

When your brain receives signals that indicate some kind of danger, the course of action is slightly different. The process above still occurs, but this higher-level analysis takes precious time. The fraction of a second it takes to fully understand what's happening might be the difference between life and death. To make sure your body is instantly prepared to face a threat, the thalamus also sends the raw sensory information via a shortcut, directly to the amygdala.

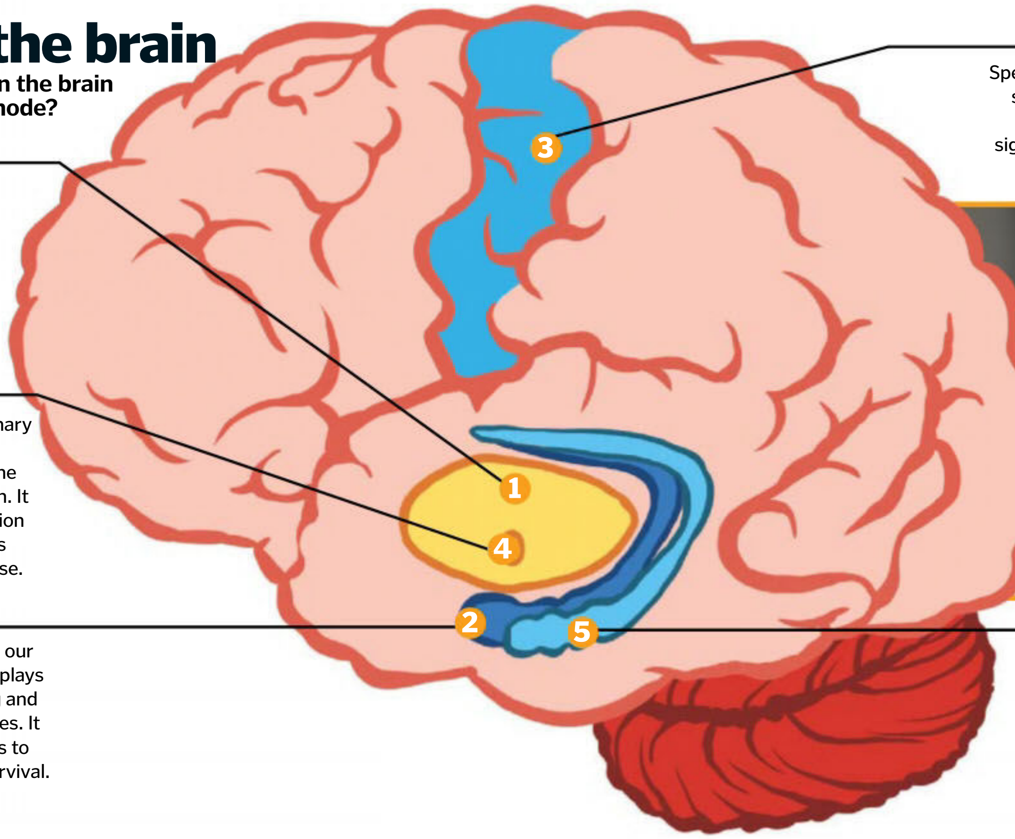
As soon as the amygdala is alerted, it signals the hypothalamus. This part of the brain activates systems that release a cocktail of around 30 different hormones into the bloodstream. One hormone in particular, adrenaline, causes a variety of physiological reactions all around the body. For example, in the lungs it makes smooth muscle cells relax, expanding the air passages so more oxygen can reach the blood. It also stimulates cardiac cells so the heart beats faster, and makes muscles in the eyes contract to dilate the pupils. The physical changes produced by this sudden flood of hormones make up what is known as the fight-or-flight response. This instinctive reaction gets you ready to either take a stand and defend yourself, or escape to safety.

Not many of us experience life-threatening situations day-to-day, so more often than not our fight-or-flight response is triggered by a false alarm. The moment of panic you feel after hearing a loud bang, for example, is because neural signals from the shortcut reach the amygdala first. The fight-or-flight response automatically kicks in before the brain evaluates the situation, just in case. Once the amygdala receives more information and concludes you aren't in danger, it signals the thalamus to stop the fight-or-flight reaction, returning your body to normal.

The human brain is hard-wired to prepare for the worst; it may seem silly to treat every loud noise as a danger, but if the threat turns out to be real, this overreaction could save your life.

Fear on the brain

What happens when the brain goes into survival mode?



Thalamus
The thalamus is the first port of call for most sensory signals from the body. It relays this information to the relevant areas of the brain, like a switchboard.

Hypothalamus
The hypothalamus's primary role is to maintain homeostasis – keeping the body in a stable condition. It also regulates the secretion of hormones and initiates the fight-or-flight response.

Amygdala
The amygdala processes our emotional reactions and plays a role in decision-making and the formation of memories. It moderates our responses to events that affect our survival.

Sensory cortex
Specific regions of the brain analyse the sensory information from each of our different senses. They process the signals passed on from the thalamus to give them meaning.

Hippocampus
The hippocampus plays an important role in long-term memory formation. It compares incoming sensory information to past events to help establish a context for the situation you face.

1 Stimulus

When a potential threat is detected, the thalamus sends signals to the amygdala via two different pathways. One route is fast and direct, while the slower path analyses the situation and decides what should happen next.

2 Act first

The first pathway immediately assumes there's danger even if there is none – a safer option than vice versa. It goes directly to the amygdala, which sends signals to the hypothalamus to initiate the fight-or-flight response.

3 Analysis

The same information is sent along the more investigative route. Signals from the thalamus are sent to the sensory cortex, which interprets the data, followed by the hippocampus, to analyse the context of the situation.

4 Fight or flight?

The hypothalamus activates both the sympathetic nervous system and the adrenal-cortical system to trigger the fight-or-flight reaction. The impulses and hormones produced prepare the body for action.

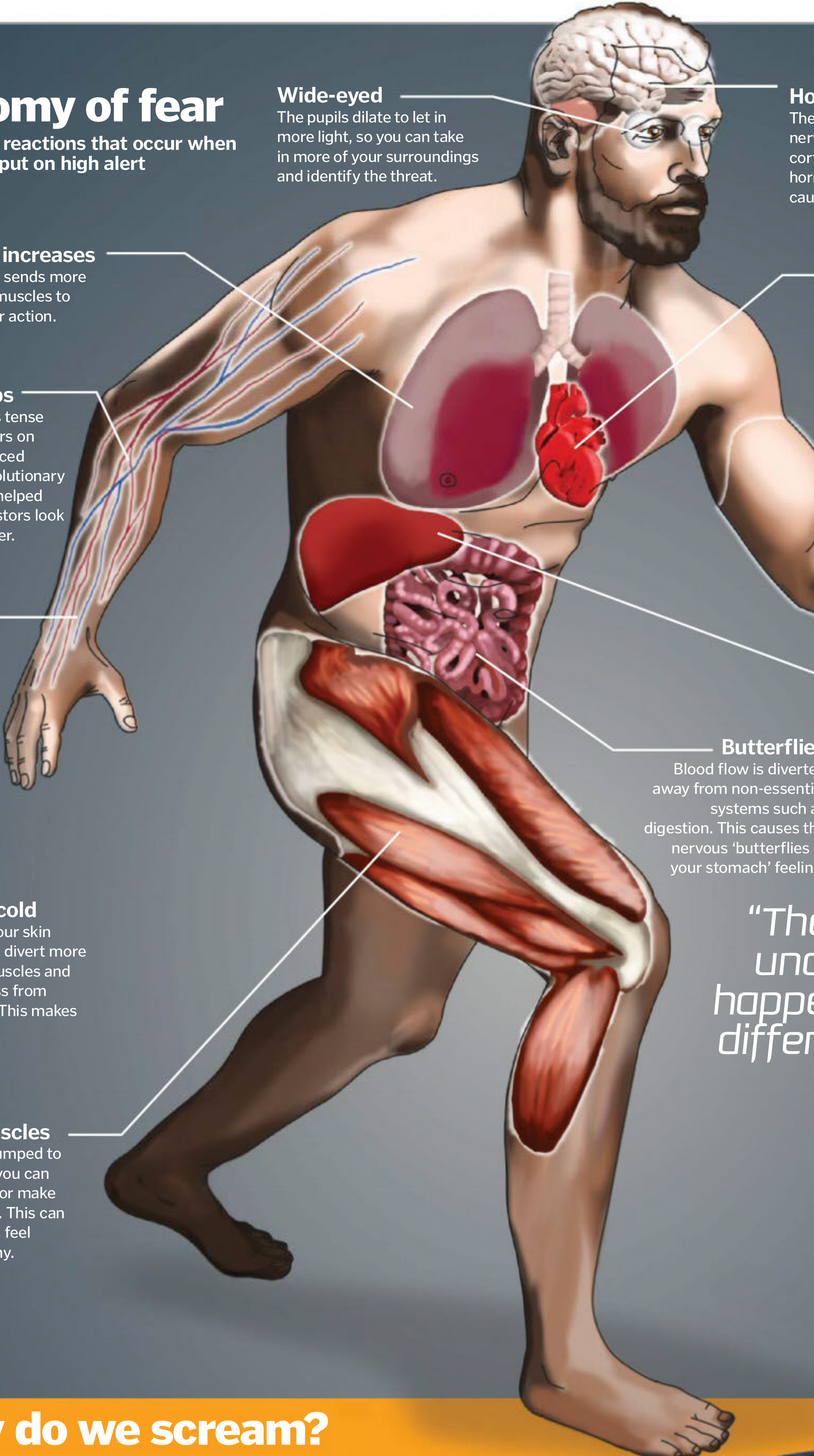
5 Judgement

Once the situation has been analysed by the longer pathway, the hippocampus sends signals to the amygdala to either seize the fight-or-flight response if there is no danger, or to maintain it if there is.

DID YOU KNOW? *The 'Wilhelm scream' sound effect has been used in over 200 films, from Star Wars to Toy Story*

Anatomy of fear

The extreme reactions that occur when your body is put on high alert



Wide-eyed
The pupils dilate to let in more light, so you can take in more of your surroundings and identify the threat.

Hormones
The activated sympathetic nervous system and adrenal-cortical system release dozens of hormones into the bloodstream to cause changes in the body.

Respiration increases
Faster breathing sends more oxygen to your muscles to prepare them for action.

Heart rate increases
The hormones adrenaline and noradrenaline are released to increase your heart rate, sending more blood to your muscles and brain.

Goosebumps
As your muscles tense up, the small hairs on your skin are forced upright. This evolutionary reflex probably helped our hairier ancestors look bigger and scarier.

Cold sweat
Your body anticipates immediate action, so you pre-emptively start to sweat in order to keep cool.

Butterflies
Blood flow is diverted away from non-essential systems such as digestion. This causes the nervous 'butterflies in your stomach' feeling.

Energy boost
Your liver starts breaking down glycogen into glucose, ready to supply the body with instant energy.

Blood runs cold
The vessels in your skin constrict to help divert more blood to your muscles and reduce blood loss from potential injury. This makes you feel cold.

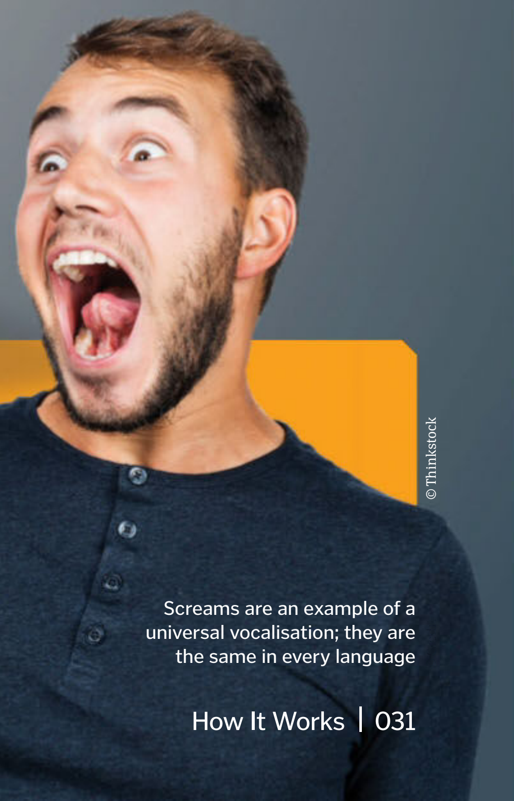
Shaking muscles
More blood is pumped to the muscles so you can defend yourself or make a quick getaway. This can make your limbs feel tense and twitchy.

> *"The time it takes to understand what's happening might be the difference between life and death"*

Why do we scream?

Screaming is an innate reflex; it's usually the first thing you do when you're born. Although we might also scream from excitement or pleasure, it is most often a cry of distress. Researchers from New York University conducted an experiment using brain scans to see how our minds react to screams. When we listen to normal speech, what we hear is sent to the auditory cortex for processing so we can make sense of the sounds.

However, the study showed that when we hear a scream, the signals are sent straight to the amygdala to activate the brain's fear response. The team also found that 'rougher' screams – those that change volume more quickly – were the most distressing. The results show that screams are a very effective method of communication in humans. They not only help convey danger, but also help make those who hear them more alert.



© Thinkstock

Screams are an example of a universal vocalisation; they are the same in every language

Are fears genetic?

Your phobias could be passed down through generations in DNA

It was previously assumed that all irrational fears are learned through personal experience or taught to us by others. In cases where a person develops a phobia related to a traumatic event in their past, this is most likely the case. If somebody nearly drowns while swimming in the sea, for instance, it wouldn't be surprising if they develop aquaphobia, the fear of water. The brain makes a connection between the situation and the feeling of pain and panic, and commits it to memory.

However, it is now thought that some phobias have a genetic origin. Identical twins are more likely to share the same irrational fears than non-identical twins, even if they are raised apart from one another.

Experiments with mice have shown that fears they develop can be passed down to their children and even their grandchildren. The mice were conditioned to fear the scent of acetophenone – a sweet smelling chemical. Researchers found that the pups, and even the grand-pups, of the conditioned mice were startled by the scent too.

One explanation for this could be that parent mice communicate with their pups to effectively teach them what to fear. Studies have found that when mice are scared, they release pheromones that act as an alarm signal to other mice. However, in the acetophenone experiment, the pups proved to be sensitive to the scent from the very first time they encountered it. What's more, some pups of conditioned mice were fostered by non-conditioned mice. The non-conditioned foster parents were not afraid of the scent, but the pups were, suggesting the fear's origin was genetic rather than social.

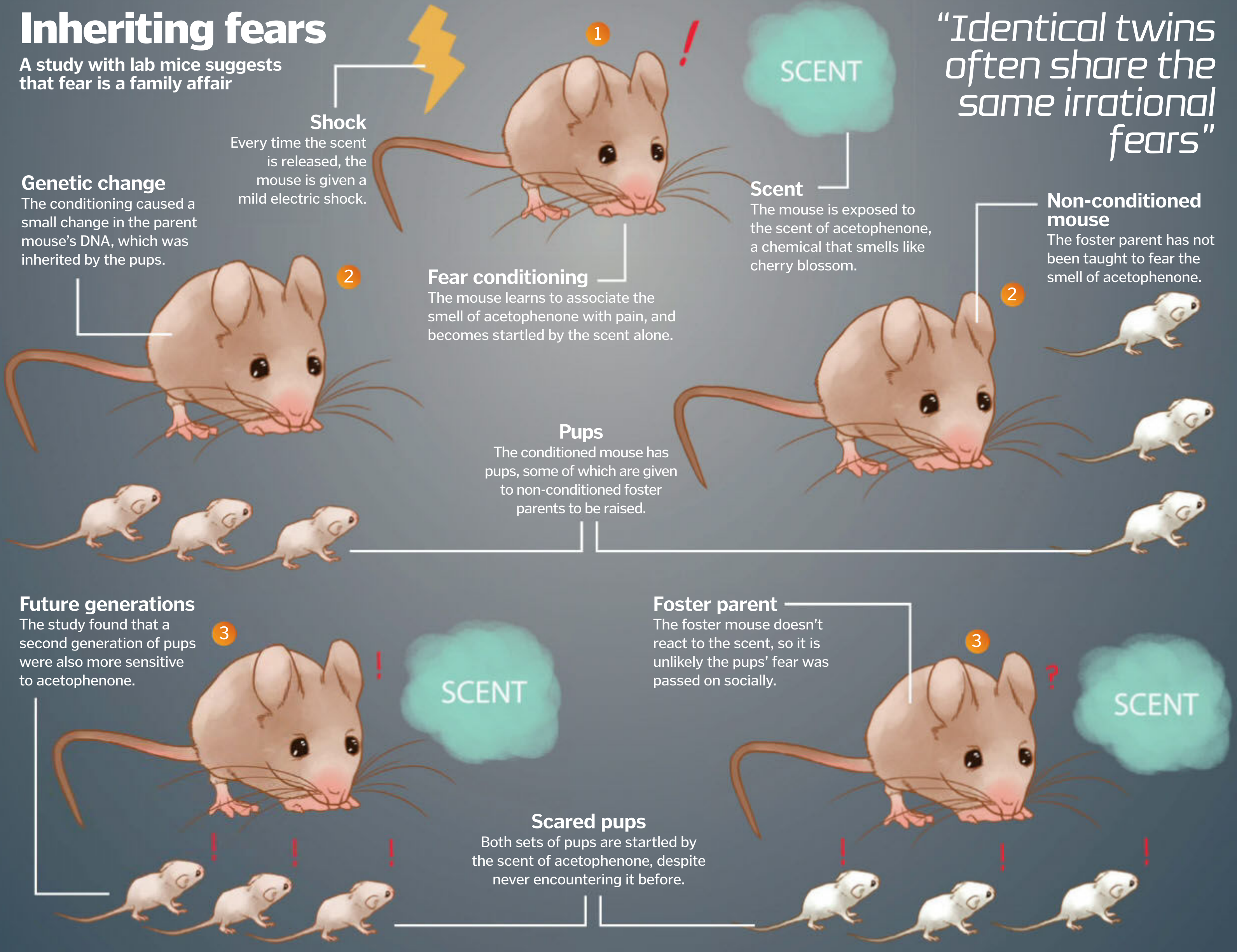
It is not clear exactly how the conditioned fear is passed on to future generations of mice, but the current theory is that it is down to something called epigenetic inheritance. The original conditioning process leads to chemical modifications that change gene expression (which genes are switched on or off), without changing the DNA sequence itself. The researchers found that the conditioned mice and their offspring developed more scent receptors in their brains compared to non-conditioned mice. With more of these receptors, they can detect the presence of acetophenone at lower concentrations and so are alerted to it more easily.

Epigenetics is a relatively new area of research, but it stands to reason that fears and other memories may well be inherited this way in humans too.

> "Identical twins often share the same irrational fears"

Inheriting fears

A study with lab mice suggests that fear is a family affair



Shock
Every time the scent is released, the mouse is given a mild electric shock.

Scent
The mouse is exposed to the scent of acetophenone, a chemical that smells like cherry blossom.

Fear conditioning
The mouse learns to associate the smell of acetophenone with pain, and becomes startled by the scent alone.

Genetic change
The conditioning caused a small change in the parent mouse's DNA, which was inherited by the pups.

Non-conditioned mouse
The foster parent has not been taught to fear the smell of acetophenone.

Pups
The conditioned mouse has pups, some of which are given to non-conditioned foster parents to be raised.

Future generations
The study found that a second generation of pups were also more sensitive to acetophenone.

Foster parent
The foster mouse doesn't react to the scent, so it is unlikely the pups' fear was passed on socially.

Scared pups
Both sets of pups are startled by the scent of acetophenone, despite never encountering it before.

DID YOU KNOW? *A growing fear in the modern world is nomophobia – the fear of being without a mobile phone*

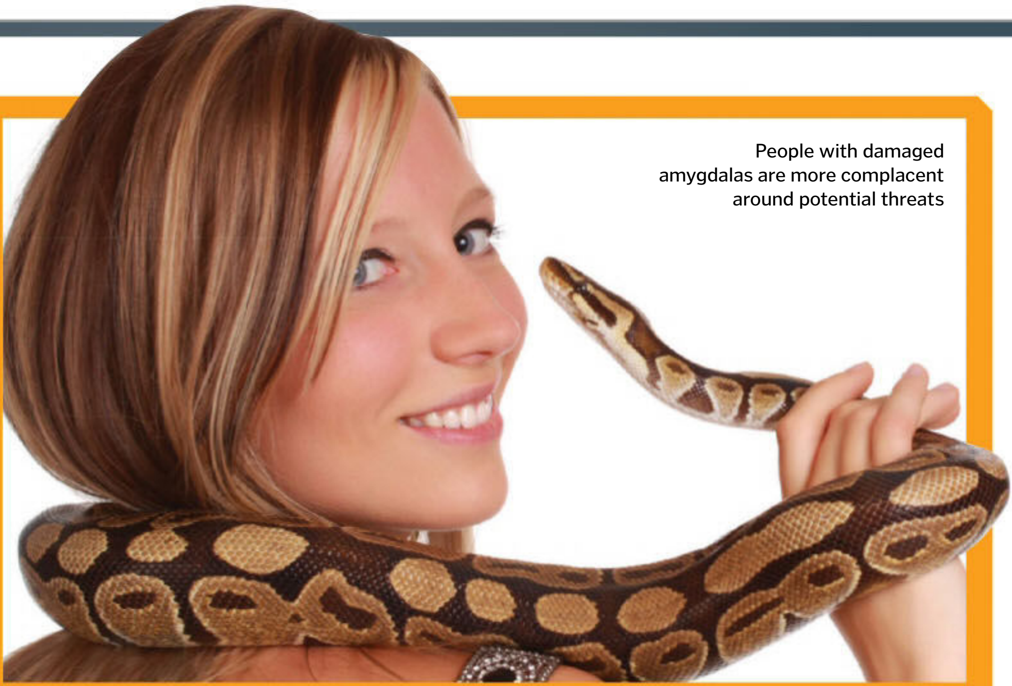
Living fearlessly

Self-help gurus and motivational posters encourage us to be fearless, but in reality a life without fear would be incredibly dangerous. Studies have shown that when the region of the brain called the amygdala is damaged, people are more likely to take risks. Severe damage can even leave people with no sense of fear whatsoever – which can land them in some pretty scary situations!

For the past 25 years, scientists have been studying a patient (known as SM for anonymity) who lacks an amygdala. SM has experienced many traumatic events in her life – she has been held at both knife and gun-point, and was nearly killed during a domestic violence attack – but she did not react with any sense of desperation or urgency, even though her life was in danger.

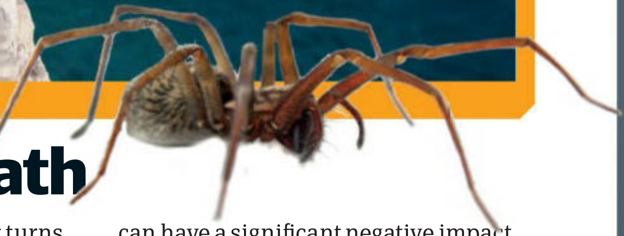
Researchers took SM to an exotic pet store where, despite claiming she hated them, the snakes and spiders captivated her. Scientists noted her curiosity and compulsive desire to touch some of the more dangerous creatures, following repeated warnings from staff. The researchers concluded that SM's inability to detect or react appropriately to threats likely contributed to her disproportionate number of traumatic experiences.

By studying patients like SM, it is hoped that scientists can understand more about fear and discover new methods of helping people whose lives are plagued by it. For example, treatments that target the amygdala could benefit those who suffer from post-traumatic stress disorder.



People with damaged amygdalas are more complacent around potential threats

Sometimes it is just the thrill that makes people take unnecessary risks



Scared to death

It's not just a figure of speech – it turns out you really can die of fright. The adrenaline released during the fight-or-flight response can be damaging in large amounts. This stress hormone encourages the heart muscle to contract, but if your body releases too much adrenaline, your heart is unable to relax again. Adrenaline can also interfere with the cells that regulate your heart rhythm, causing it to beat abnormally, which could be lethal.

While not directly deadly, prolonged anxiety can have a significant negative impact on your health. The fight-or-flight response suppresses the immune system, leaving you vulnerable to illness. Going into survival mode on a regular basis can lead to digestive disorders as this non-essential system is repressed. Long-term stress can also lead to weight issues by disrupting the metabolism; elevated levels of cortisol can make the body less sensitive to insulin. Muscles that are constantly tense and ready for action can cause headaches, stiffness and neck pain. The list doesn't end there; chronic anxiety has also been linked to cardiovascular problems, asthma and insomnia. Such a broad range of effects can be harmful to both physical and mental wellbeing.

Regularly activating the fight-or-flight response through anxiety or stress can cause serious health problems

© Thinkstock; Dreamstime

Fear is an instinctive survival mechanism that helps protect us from danger

Facing your fears

Can you retrain your brain to overcome a phobia?

Some phobia triggers are much easier to avoid than others. For example, people who suffer from a fear of bats (chiroptophobia) are highly unlikely to be plagued by these creatures day in, day out. Someone suffering from a social phobia, however, will struggle to lead a normal life.

There are a variety of different methods used to treat phobias. Among the most popular are talking treatments, such as cognitive behavioural therapy and exposure therapy, which work by retraining the brain to change how it responds to a phobia trigger. The approach is essentially the opposite of fear conditioning – the patient learns to associate their trigger with more rational, positive thoughts.

Another approach being investigated is tricking the brain into treating itself. Mentalist and illusionist Derren Brown conducted an experiment on his programme *Fear And Faith*, in which he gave people with different phobias a new wonder drug called Rumyodin. One subject, usually terrified of heights, was comfortably able to sit on the edge of a tall bridge. Another volunteer with a fear of performing in public was able to go to an audition. It was revealed that Rumyodin (an anagram of 'your mind') didn't exist, and the participants had simply been injected with saline solution and given sugar pills.

The incredible results are a demonstration of the placebo effect, a phenomenon in which a fake treatment has a very real result. Scientists are investigating how this effect can be exploited to treat both physical and psychological problems.

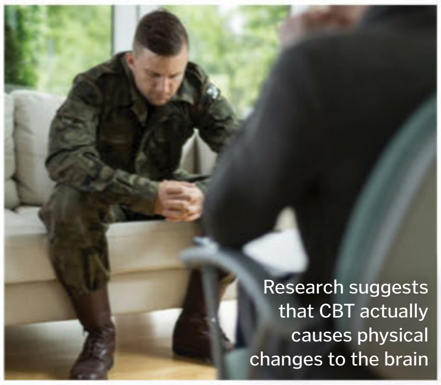
Phobia treatments

Exposure therapy involves facing your fears one step at a time

> *"The patient learns to associate their phobia trigger with more rational, positive thoughts"*

Exposure therapy

The aim of exposure therapy is to gradually desensitise the patient to the source of their phobia. The patient ranks situations from least to most terrifying. For example, an arachnophobe might place thinking about a spider at the bottom of their list, and having a spider crawl along their arm at the top. The patient works with a psychologist to systematically work their way through the list, using relaxation techniques or other coping mechanisms until they are comfortable with each stage. The patient's brain learns to relate each scary situation to being calm, reducing their anxiety.



Research suggests that CBT actually causes physical changes to the brain

Cognitive behavioural therapy

The aim of cognitive behavioural therapy (CBT) is to change how we think about certain situations. It is thought that irrational anxiety issues are caused by a patient's negative interpretation of events, rather than the events themselves. CBT is a talking therapy that helps patients assess their reactions to situations, replacing the worry cycle with more useful or realistic thoughts. Patients' brain scans indicate that CBT reduces the overactivity in the amygdala and hippocampus associated with phobias. Studies have also shown that CBT is as effective as medication in the treatment of many anxiety disorders.

Therapists can control the virtual scenario to suit the patient's progress

Virtual reality therapy

Exposure therapy isn't a viable option for all phobias, but modern technology offers an alternative. Advancements in virtual reality systems mean that patients can now face their fears through a headset rather than in the real world. This allows patients to face any number of situations relating to their phobia, while knowing they are in no physical danger. For example, somebody with a phobia of flying can take a course of sessions – in which they board a virtual plane and experience announcements, take-off, turbulence and landing – without having to buy a plane ticket each week.

DID YOU KNOW? *Anatidaephobia, the fear that a duck is watching you, is fake – it was invented for a cartoon*

Top 10 strangest phobias

The most common phobias stem from rational fears, but others are completely bizarre

Papaphobia
An irrational phobia of the Pope

Heliophobia
Fear of the Sun, sunlight, or bright lights

Trypophobia
An intense fear of small holes or bumps

Xanthophobia
The fear of the colour or word yellow

Phobophobia
The fear of developing a phobia

Soceraphobia
An irrational fear of your parents-in-law

Somniphobia
The fear of falling asleep

Lutraphobia
The irrational fear of otters

Arachibutyrophobia
The fear of having peanut butter stuck to the roof of your mouth

Omphalophobia
The fear of belly buttons

© Thinkstock; Dreamstime

Perfect posture

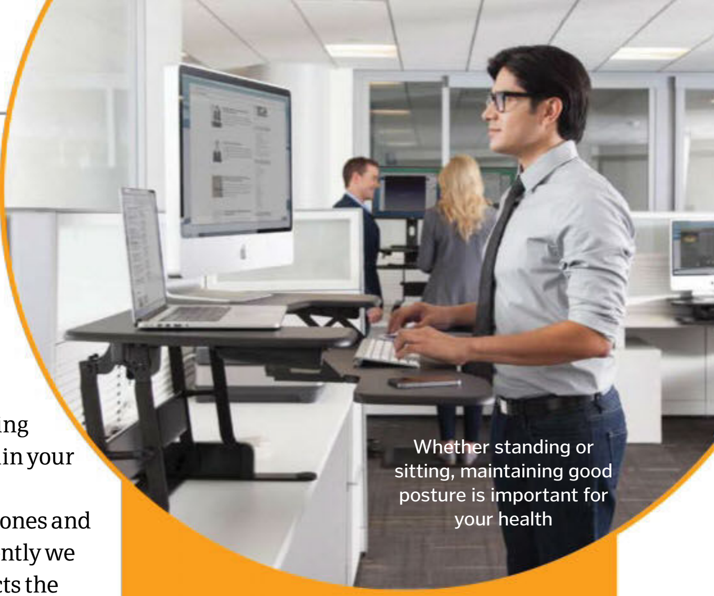
Find out how being a serial sloucher affects more than just your spine

Chances are most of you reading this aren't sitting or standing properly. Students and office workers know only too well how easy it is to slip into a slouch while spending all day working at a desk. This prolonged poor posture puts stress on the neck, shoulders and spine, contributing to problems such as postural hunchback and spinal misalignment.

Good posture ensures that you can stand, sit or lie down in positions that put the least strain on your body's muscles and ligaments. A quick way to check your posture is to make sure your earlobes are aligned over the middle of your shoulders, your shoulders are in line with your hips, and your hips are directly above your knees and ankles. This correct positioning may take some practice, but as you retrain your muscles it becomes second nature.

In addition to putting stress on your bones and muscles, bad posture affects how efficiently we breathe. Hunching the shoulders restricts the amount by which the ribcage can expand, reducing lung capacity by as much as 30 per cent. Poor posture has also been linked to neurological issues and heart disease.

A surprising side effect of posture is that it can change how people think. A study by Ohio State University in the US found that people who sat up straight exhibited a more confident and positive outlook than those who slumped over.



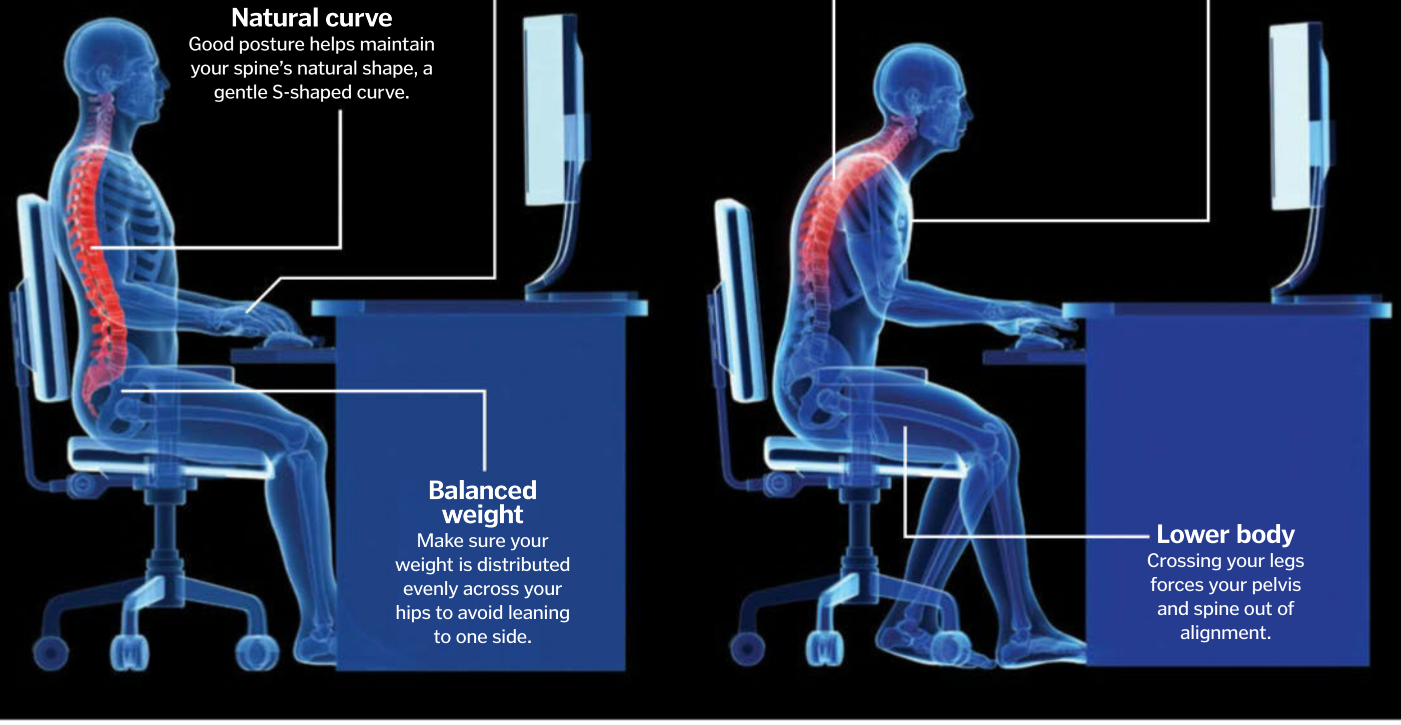
Whether standing or sitting, maintaining good posture is important for your health

Sit-stand desks

With research highlighting the negative health effects of sedentary lifestyles, sit-stand desks like the VARIDESK are becoming more popular. These adjustable platforms make it easy to alternate between sitting and standing throughout the day, to avoid staying fixed in the same position for hours at a time. Find out more at **www.varidesk.com**.

Seated posture

How sitting up straight protects your spine



Arms
Avoid resting your weight on your forearms or elbows, as this can strain your shoulders and upper back.

Strain
Bad posture works against the natural curvature of your spine, putting stress on the muscles.

Hunching over
Spending hours hunched over a desk can tighten your chest and weaken your upper back.

Natural curve
Good posture helps maintain your spine's natural shape, a gentle S-shaped curve.

Balanced weight
Make sure your weight is distributed evenly across your hips to avoid leaning to one side.

Lower body
Crossing your legs forces your pelvis and spine out of alignment.

Breaking bad habits

Most of us are guilty of these common posture mistakes, but luckily they can be corrected

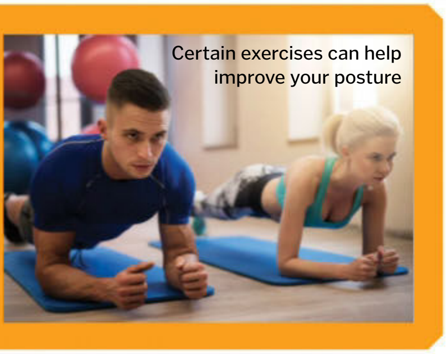
Slouching
Reclining with no lower back support can feel comfortable as it requires less muscular effort, but over time this puts pressure on some muscles while weakening others.

'Donald Duck' posture
Frequently wearing high heels or being pregnant can pitch your weight forward, so your upper body leans forward of your hips and your bottom sticks out.

Jutting chin
Poking your chin out when viewing a screen is a by-product of poor posture. Hunched shoulders angle the neck and head down, so the chin is lifted to keep looking forward.

Standing on one leg
Leaning on one leg, rather than having your weight evenly distributed between both of them, puts extra pressure on one side of your lower back and hips.

THE SOLUTION
Practise makes perfect! Consciously correcting your posture will help improve it over time. Strengthening your core with exercises like back extensions and planks will also help re-train weakened muscles.



Certain exercises can help improve your posture

© Thinkstock

“Speak French, Spanish or Italian as they are *really* spoken”

Now you can improve or maintain your French, Spanish or Italian with the bi-monthly audio magazines, *Bien-dire, Punto y Coma* and *Tutto Italiano*.

Bien-dire, Punto y Coma and *Tutto italiano* are all published six times a year from France, Spain and Italy and include a glossy magazine packed full of lively, topical and original articles and in-depth interviews in French, Spanish or Italian to give you the inside track on French, Hispanic or Italian culture. Key words and phrases are glossed into English on the facing page. The articles, in turn, are narrated on the accompanying 60-minute audio CD to enable you to improve your listening comprehension and understand French, Spanish or Italian as it's really spoken. In addition, every feature is graded for difficulty so that you can assess your progress with each issue.

If you now want to be able to speak like a native, a subscription to *Bien-dire, Punto y Coma* or *Tutto italiano* will inspire, motivate and help you to achieve fluency.

Key Benefits

- Speak French, Spanish or Italian with confidence by learning the language as it's *really* spoken
- Improve your vocabulary and listening comprehension
- Improve your knowledge of French, Hispanic or Italian culture
- Lively, relevant and up-to-date, authentic content
- Take advantage of on-going, portable and flexible learning

SPECIAL OFFER
£51 Saving!

Subscribe Today to either *Bien-dire, Punto y Coma* or *Tutto italiano* for a year for just £89 (normal price £99) and you will receive an extra issue, worth over £16 for FREE, and a FREE electronic dictionary bookmark worth £24.99 - a combined saving of £51!

Order TODAY By calling
0800 141 2210

Outside the UK call
+44 117 927 2236

Or order by visiting our website:
www.languages-direct.com/HWM116

Subscribe Today!

01. Please send me a year's subscription (6 bi-monthly magazines and 6 accompanying audio CDs for £89) to ***Bien-dire* French Audio Magazine** + 1 Extra FREE Issue and a FREE French-English electronic dictionary! ☐

02. Please send me a year's subscription (6 bi-monthly magazines and 6 accompanying audio CDs for £89) to ***Punto y Coma* Spanish Audio Magazine** + 1 Extra FREE Issue and a FREE Spanish-English electronic dictionary! ☐

03. Please send me a year's subscription (6 bi-monthly magazines and 6 accompanying audio CDs for £89) to ***Tutto italiano* Italian Audio Magazine** + 1 Extra FREE Issue and a FREE Italian-English electronic dictionary! ☐

Cheque: Cheque enclosed for £89 (payable to Languages Direct Ltd) ☐
or Card: Please charge my credit card for the sum of £89 only Mastercard ☐ Visa ☐ Amex ☐
Card number: ____
Expiry date: ____ Card CVV Code: ____
First name: ____ Last name: ____
Address: ____
Postcode Country
Telephone: ____ Email: ____

Please send your completed order form together with payment to:

Languages Direct Ltd

FREEPOST RSKB-KSKR-LYLU, Bristol BS1 6UX

Delivery: Your first issue should be with you within 10 days of receiving your order.

Outside the UK send to:

Languages Direct, Spike Island, 133 Cumberland Road,
Bristol, BS1 6UX, United Kingdom

60 day money-back guarantee

If for any reason *Bien-dire, Punto y Coma* or *Tutto italiano* is not for you, just let us know within 60 days, and we'll refund your subscription in FULL, and you can keep your first issue. If at any time later you decide to cancel, we'll refund you the cost of any unmailed issues.

To see our full range of excellent language learning materials visit **www.languages-direct.com**

Media Ref: HWM116

Isolating deadly diseases

When serious infection strikes, biocontainment units work to keep us safe

Hazard group 4 pathogens – such as smallpox, Lassa fever and Ebola – cause severe human disease. They are likely to spread, and there is usually no effective prevention or cure, so when infected patients come through the door, hospitals must act fast. The patients may be rushed to a separate facility known as a biocontainment unit. There are only a small number of these facilities worldwide, and every detail is geared towards infection control.

Biocontainment units are designed to be isolated from the main hospital, providing everything that the staff and patients might need in one safe, sealed space. The rooms have facilities for normal, high-dependency and emergency care; there are en-suite bathroom facilities, and staff can even perform minor surgery. Dedicated lab facilities allow tests to be performed immediately, without the need to transport dangerous samples.

To minimise the chance of airborne pathogens escaping into the hospital, these units have their own dedicated ventilation systems, and the pressure inside is kept slightly lower than the pressure outside. This means that air will have a natural tendency to move inwards, creating a constant breeze that helps to blow any infectious particles back inside.

All air leaving the facility is first passed through high-efficiency particulate air (HEPA) filters. These dense mats of glass fibres block, slow and stick to particles, filtering contaminants and preventing their escape. The filtered air is released high above the roof of the hospitals, dissipating into the atmosphere.

Inside the unit are clear divisions between the rooms. Staff members enter through designated areas to don their protective equipment, and exit through different areas to take it off again. The rooms are fitted with glass panels and intercom systems, and CCTV allows close patient monitoring, while minimising the risk of infection.

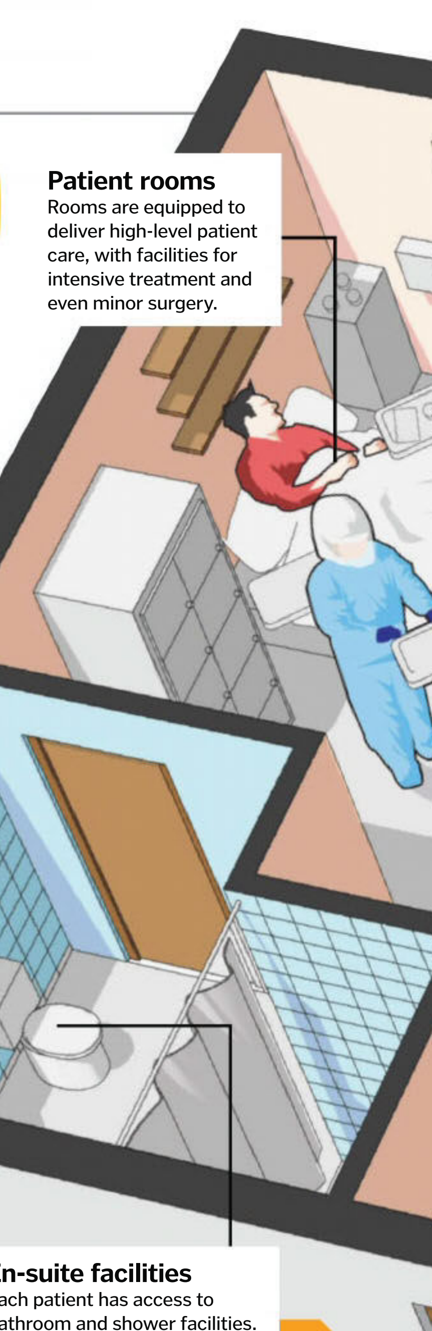
Nothing that goes in to the unit can come out until staff are sure it is clean. Items like suits, swabs and spoons are sterilised, either by searing steam or high-heat and high-pressure autoclaves. Disposable items are burnt.

Patient waste is bleached until nothing can survive, lab samples are dunked in sterilisation tanks before they are taken for testing, and some equipment is exposed to burning ultraviolet radiation. All of these measures help to ensure that the patients inside and outside the unit receive the best possible care, while minimising the risk of further infection.

Autoclaves sterilise equipment with high pressure and high temperatures

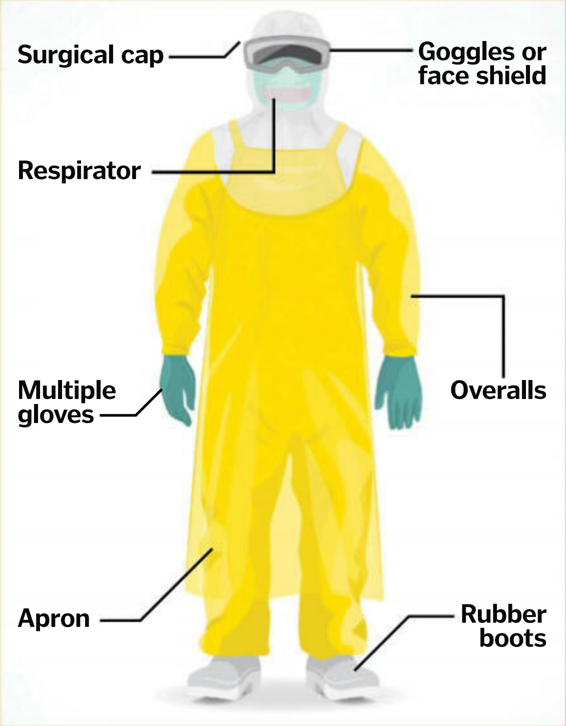
Inside a biocontainment unit

The extreme measures that help to prevent outbreaks



Patient rooms
Rooms are equipped to deliver high-level patient care, with facilities for intensive treatment and even minor surgery.

En-suite facilities
Each patient has access to bathroom and shower facilities.

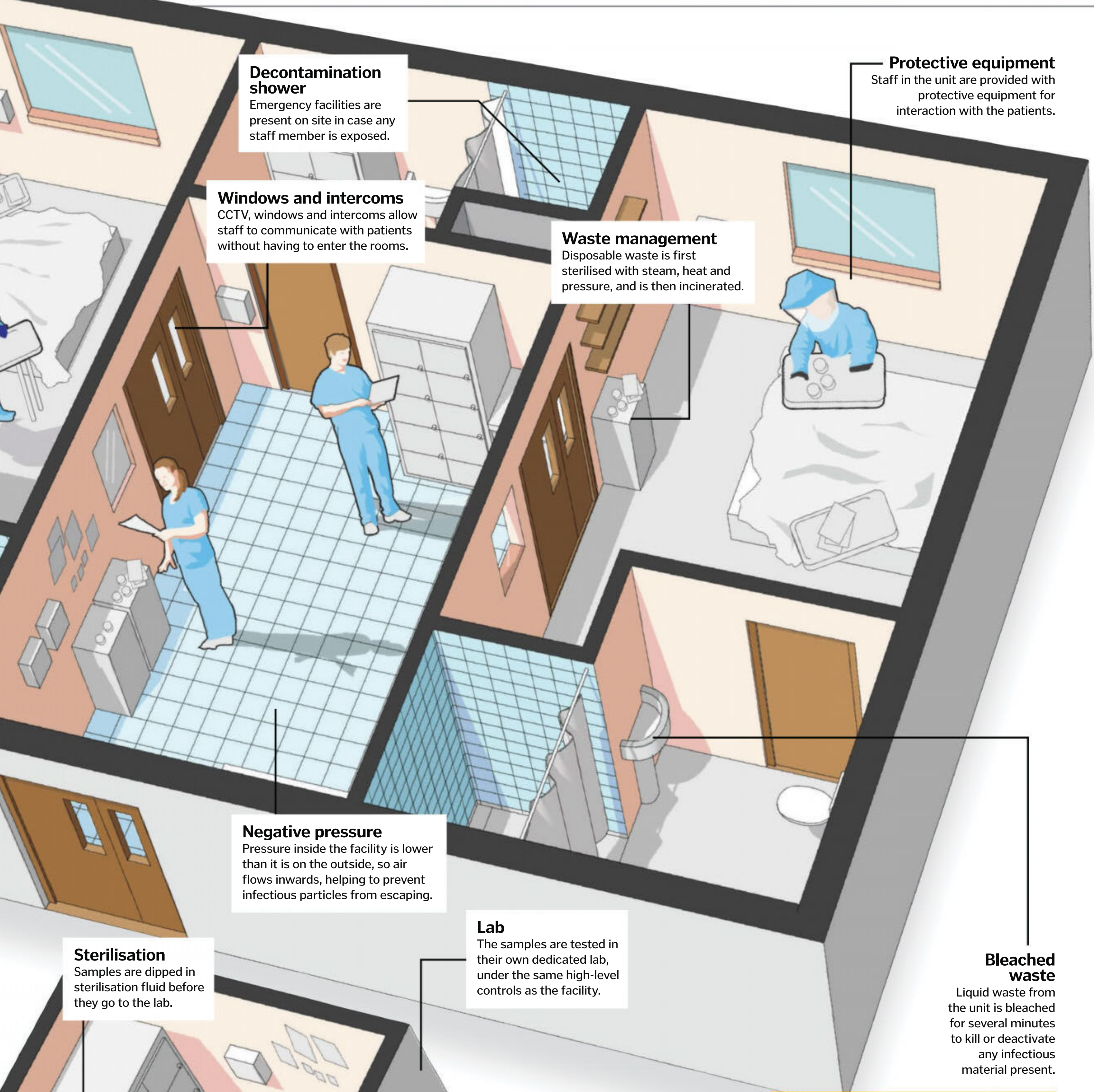


Keeping staff safe

No amount of bleach would protect against infectious disease without highly trained medical staff. The selection process to become a member of a biocontainment unit team is rigorous. On top of their medical expertise, dedicated unit staff are educated in microbiology, sterilisation, disinfection, emergency planning and laboratory maintenance.

The medical teams wear several layers of protection when interacting with patients inside the units. They are covered from head to toe, and staff are employed specifically to help the team get dressed and undressed for work. They wear full body suits that include respirators to clean the air they breathe, and their hands are protected by several pairs of gloves. All of this equipment needs to be put on and taken off in a specific order every time they enter or exit the unit, and there are specialist areas that a low this to be done safely.

DID YOU KNOW? *There are only four specialist biocontainment hospital units in the US and two in the UK*



Decontamination shower
Emergency facilities are present on site in case any staff member is exposed.

Protective equipment
Staff in the unit are provided with protective equipment for interaction with the patients.

Windows and intercoms
CCTV, windows and intercoms allow staff to communicate with patients without having to enter the rooms.

Waste management
Disposable waste is first sterilised with steam, heat and pressure, and is then incinerated.

Negative pressure
Pressure inside the facility is lower than it is on the outside, so air flows inwards, helping to prevent infectious particles from escaping.

Lab
The samples are tested in their own dedicated lab, under the same high-level controls as the facility.

Sterilisation
Samples are dipped in sterilisation fluid before they go to the lab.

Bleached waste
Liquid waste from the unit is bleached for several minutes to kill or deactivate any infectious material present.

> "Nothing that goes in to the unit can come out until staff are sure it is clean"

Sample tubes are dunked to sterilise the outside before they are sent for testing

© Dreamstime; Illustration by Ed Crooks

HOW IT WORKS

YouTube

Subscribe to our channel to see ***your curious questions*** answered on camera

youtube.com/howitworksmag

Seeing at sea

How do Fresnel lenses help lighthouses shine far into the ocean?

Lighthouses help to mark jagged rocks, warning sailors to stay away

Lighthouses are topped with bright beacons that help to mark dangerous rocks at night. However, bright lights don't always reach far enough into the ocean to be seen. The solution, which was designed back in the 1800s, is a Fresnel lens.

When light travels from one medium to another, it changes direction. In order to make the light travel even greater distances, glass or plastic lenses can be used to bend the rays, so that they all travel in the same direction.

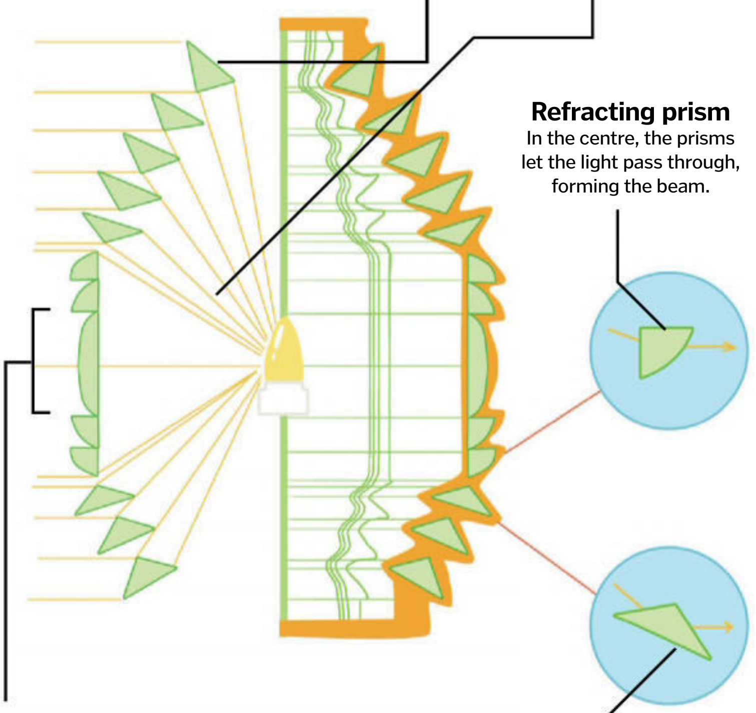
Lenses are used to bend light into crisp, magnified images in microscopes and telescopes, but these are heavy and expensive. For lighthouses, you don't need good image quality; you just need the light to travel as far as possible.

Fresnel lenses strip away all of the excess glass in order to produce a cheap and lightweight solution. The most important part of the lens is the surface, where the light comes out, moving from the glass back into the air. Fresnel lenses work by effectively cutting away the other parts.

The curved front sections are stacked together to form a ridged lens. Each step bends the light inwards a little more, focusing it into a tight, powerful beam that can then travel several kilometres out to sea.

Prism break

Stacks of prisms bend the light into a powerful beacon



Beam
The stepped lens bends the incoming light into a beam.

Light
The light produced by the bulb travels out in all directions.

Refracting prism
In the centre, the prisms let the light pass through, forming the beam.

Deconstructed lens
The middle section looks like the front of a normal lens, with most of the glass cut away.

Reflecting prism
Around the outside of the lens, the prisms reflect the light, bending it inwards even more.

© Dreamstime; Illustration by Rebekka Hearl

DID YOU KNOW? *The Doppler effect is used in some types of radar to measure the velocity of detected objects*

The Doppler effect

HOW SOUND AND LIGHT WAVES CHANGE AS THEY MOVE TOWARDS OR AWAY FROM US

BACKGROUND

In the early 1840s, Austrian physicist Christian Doppler was the first to describe how sound and light waves seem to change as the distance between the source and an observer is increasing or decreasing. The theory was tested in 1845 by Christoph Buys Ballot. In his experiment, he asked musicians to play a constant note while on a moving train cart. The note he heard from the platform changed as the train sped past.

IN BRIEF

We've all heard how a siren changes as an ambulance rushes past. The pitch of an approaching siren will increase, then decrease as the vehicle speeds away. This is known as the Doppler effect, and is caused by sound waves effectively bunching together or stretching out. The pitch you hear is determined by the sound's frequency, or the number of waves per second. The siren's frequency doesn't change, but as the ambulance travels towards you, the same number of waves are compressed into a decreasing distance. This increases the frequency of the sound waves you hear, so the pitch seems higher. As the ambulance travels away, the sound waves are spread across a growing distance, reducing the frequency you hear so the pitch seems lower.

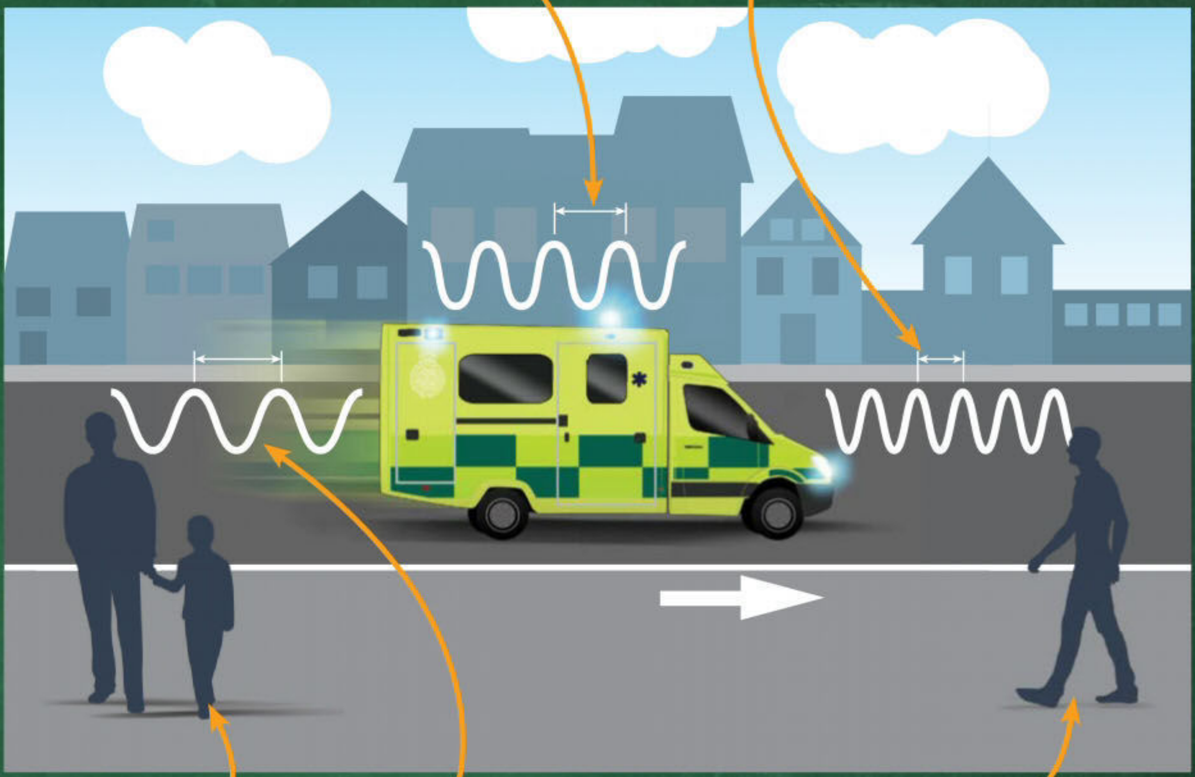
It's all relative: to people travelling in the emergency vehicle, the siren's pitch stays the same

SUMMARY

A sound's apparent pitch is relative to the changing distance between the source and the observer. Decreasing distances result in a higher pitch and increasing distances result in a lower pitch.

Doppler in action

Why the pitch of a siren seems to rise and fall



Siren
The siren actually blares at a constant frequency. To the ambulance driver, the pitch of the siren remains the same.

Driving towards
As the ambulance travels towards the observer, the waves are compressed into a smaller distance.

Observer 1
The apparent increase in wavelength and decrease in frequency is heard as a lower pitched siren.

Driving away
As the ambulance travels away, the same number of waves are spread over a larger distance.

Observer 2
To this observer, the siren's frequency appears to increase and its wavelength decrease, giving the impression of a higher pitch.

REDSHIFT AND BLUESHIFT

THE PRINCIPLE OF THE DOPPLER EFFECT APPLIES TO LIGHT AS WELL AS SOUND. THE FREQUENCY OF A LIGHT WAVE INDICATES ITS COLOUR, SO BY STUDYING HOW THE LIGHT OF A MOVING OBJECT CHANGES, IT IS POSSIBLE TO DETERMINE WHETHER IT IS MOVING TOWARDS OR AWAY FROM US.

THIS IS THE METHOD THAT AMERICAN ASTRONOMER EDWIN HUBBLE USED TO CONCLUDE THAT MOST GALAXIES ARE MOVING AWAY FROM OUR OWN, THEREFORE THE UNIVERSE MUST BE EXPANDING. THE LIGHT FROM MOST COSMIC OBJECTS IS SHIFTED TOWARDS THE LOWER-FREQUENCY, RED END OF THE VISIBLE LIGHT SPECTRUM. THE LIGHT FROM SOME STARS AND GALAXIES IS SHIFTED TOWARDS THE BLUE END OF THE SPECTRUM, IMPLYING THEY ARE MOVING TOWARDS US.

The physics of dance

Ballet dancers perform a precise balancing act every time they take to the stage

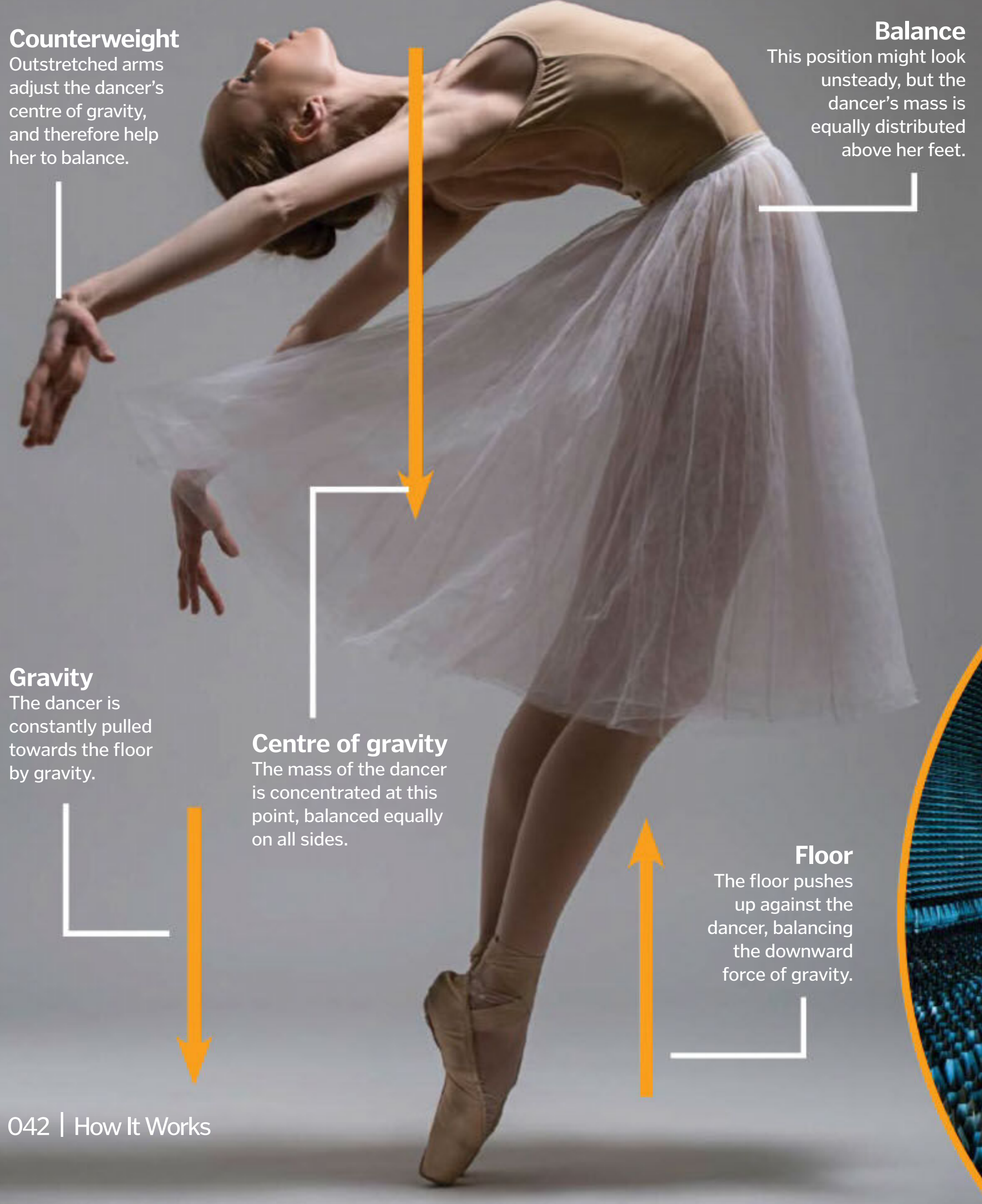
Gravity pulls ballet dancers downwards, while the floor pushes up, counteracting and balancing the force. But balanced forces don't necessarily mean a balanced dancer. Mass is the overall amount of matter that the dancer has inside their body, and to stay on their feet, they need to ensure that the centre point of that mass remains right above the spot where their feet touch the floor.

If the dancer were spherical, their centre of mass would be smack in the middle, making balancing easy. But they have a head, arms and legs, and each time they move, their centre of mass moves too. This makes balancing more challenging, but by using their limbs as counterweights, dancers can stay upright in the most incredible poses.

The dancer's feet in contact with the floor also generate another force: friction. This stops them slipping as they move, and it can also be used to generate torque, or spin. During spins, arms and legs can be used to stunning effect. Thanks to the law of conservation of angular momentum, if a dancer brings their arms and legs inwards during a spin, they will spin faster. Bringing them out again can slow the dancer down to a gentle stop.

Ballet forces

Dancers work hard to keep their centre of mass in line with the floor



Counterweight
Outstretched arms adjust the dancer's centre of gravity, and therefore help her to balance.

Balance
This position might look unsteady, but the dancer's mass is equally distributed above her feet.

Gravity
The dancer is constantly pulled towards the floor by gravity.

Centre of gravity
The mass of the dancer is concentrated at this point, balanced equally on all sides.

Floor
The floor pushes up against the dancer, balancing the downward force of gravity.

The quietest place on Earth

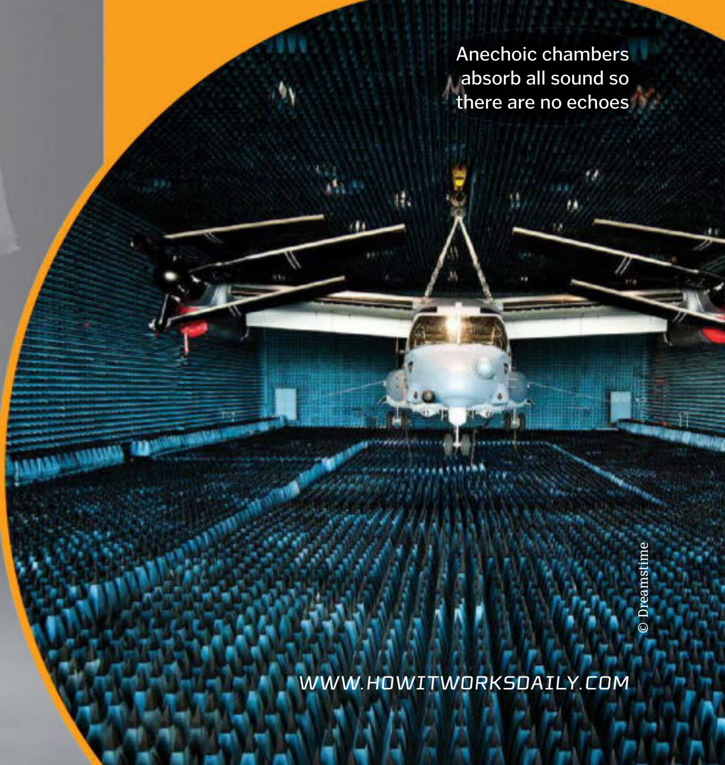
The extraordinary rooms that make it possible to hear your own heartbeat

You haven't truly experienced silence until you've been in an anechoic chamber. These rooms are made from heavy concrete with rubber-sealed doors to prevent any sound at all from getting in. Inside, the walls are covered in foam wedges to absorb internal noise, and the floor is a suspended mesh to eliminate the sound of footsteps. Every inch is designed to absorb reflections of sound waves, so you hear absolutely nothing.

These chambers are mainly used to test the performance of speakers, microphones and other products, but they also help astronauts to prepare for the eerie silence of space. The longest anyone has been able to bear the quiet for is 45 minutes.

Orfield Laboratories, which is in the US, currently holds the Guinness World Record for the quietest place on Earth, as the walls can absorb 99.9 per cent of sound.

In this environment, all a person can hear is the thumping of their heart, which can quickly drive them crazy, and with no perceptual cues to help them balance, it's also incredibly disorientating and difficult to stand or move. So next time you wish for a bit of peace and quiet, think again.



Anechoic chambers absorb all sound so there are no echoes

© Dreamstime

NEW MAGAZINE SPECIAL LAUNCH OFFER

TRY 3 ISSUES FOR JUST £1*

Explore History

Must-see heritage sites, fascinating stories & insider travel tips for those who live history

NEW
DISCOVER THE REAL DOWNTON ABBEY
Explore History
PRAGUE
The 35 World Heritage Wonders

From the Great Wall of China to your local museum, Explore History takes you on a journey around the world, and into the past. With stunning photography, fascinating stories and insider tips for your next trip, each issue of Explore History contains all the inspiration you need to get out there and discover history's greatest places.

CALL THE ORDER HOTLINE
0844 826 5022

OR ORDER ONLINE
imaginesubs.co.uk/explore
and enter code NEW161XT

*Terms and conditions: This offer entitles UK Direct Debit subscribers to receive their first 3 issues for £1. After these issues, subscribers will then pay £17.95 every 6 issues. Subscribers can cancel this subscription at anytime. Offer code NEW161XT must be quoted to receive this special subscription price. Details of the Direct Debit Guarantee are available on request. This offer expires 30 September 2016. Imagine Publishing reserves the right to limit this type of offer to one per household.

THE SCIENCE OF FOOTBALL

REVEALED: THE TECH AND TACTICS THAT TAKE TEAMS TO THE TOP

DID YOU KNOW? *There is an app called Score! that lets you recreate classic goals from famous players by swiping your screen*

> "We can predict what a football match of the future may be like based on current tech"

Picture it now: it's the 2050 World Cup final. Three-time winners China are facing off against Germany in the newly renovated Wembley Stadium. Around the world, millions of fans sit in their homes wearing virtual reality (VR) headsets; they all have the best seat in the house, right on the half-way line for kick-off. As the first goal is scored, the VR viewpoint switches to that of the player and suddenly millions of people are seeing the goal as the striker saw it, then as the goalkeeper, then from behind the goal. Those that couldn't get to their VR headsets watch the replay projected as a 3D hologram by their smartphones, and as the players run to the corner to celebrate with their fans, biometric sensors built into their kits, or even their skin, give the team managers minute-by-minute readouts of their fitness levels.

It might sound far-fetched, but when you think back to football matches just 20 or 30 years ago, it's astonishing how far the game has come in such a short time. Some of the things we take for granted in the modern game still weren't even part of the rules back then – did you know, for example, that shin pads weren't even made compulsory by FIFA until 1990? When you consider what has changed, the concepts above don't seem so unlikely.

Recent advancements in tech like VR, camera systems and even kit design have meant that the latest competitions have been the most sophisticated yet. And, with more and more technology being introduced at each tournament, the future of the beautiful game is likely to be one that is as reliant on computers and smartphones as it is on players at the top of their game.

The exciting thing is that we can predict what a football match of the future may be like based on the technology that has been added to the game in recent years, and advancements that are being developed right now. Whether it's simple things, like the disappearing spray now carried by referees, or more cutting-edge tech like cameras that allow for 3D replays, read on to discover how football matches will evolve even further in the next few years.

World Cup tech

The gadgets and gizmos that made the 2014 World Cup the most advanced yet

Smartphones and apps

Smartphones are now the primary communication devices for millions of people, and a huge selection of apps allowed for fans to show their support, and discuss their favourite teams with other fans online.

Brazuca ball

By far the most important part of the game, Adidas' 'Brazuca' ball used six polyurethane panels that are bonded to keep the ball exactly the same throughout the game. Its aerodynamics were even studied in a NASA wind tunnel!

Vanishing spray

This smart spray can be used by the referee to mark free kick lines. It is made up mostly of water and butane gas, which expands when sprayed to form bubbles. The bubbles collapse after around a minute, leaving only water on the pitch.

Nike Mercurial Superfly

Boot technology also advanced for the World Cup. Nike's Mercurial Superfly boots added a micro-textured upper that made it feel like players weren't even wearing boots, while providing excellent stability.

Nike kit

To combat the intense temperatures in Brazil, kit manufacturers focused on creating more airflow through their kits. Nike's jersey, for example, combined polyester and cotton to create 56 per cent more airflow than previous versions.

Goal-line tech

The 2014 World Cup was the first to use goal-line technology. Seven cameras at different angles accurately track the ball, and notify the referee if it crosses the line.

Portugal's 2016 kit features Nike's AeroSwift technology for improved breathability, stretch and fit

© Adidas; Nike; PixelSquid; Illustrations by Rebekka Hearl

TRAINING TEAMS OF THE FUTURE

The techniques that will take footballers to the next level

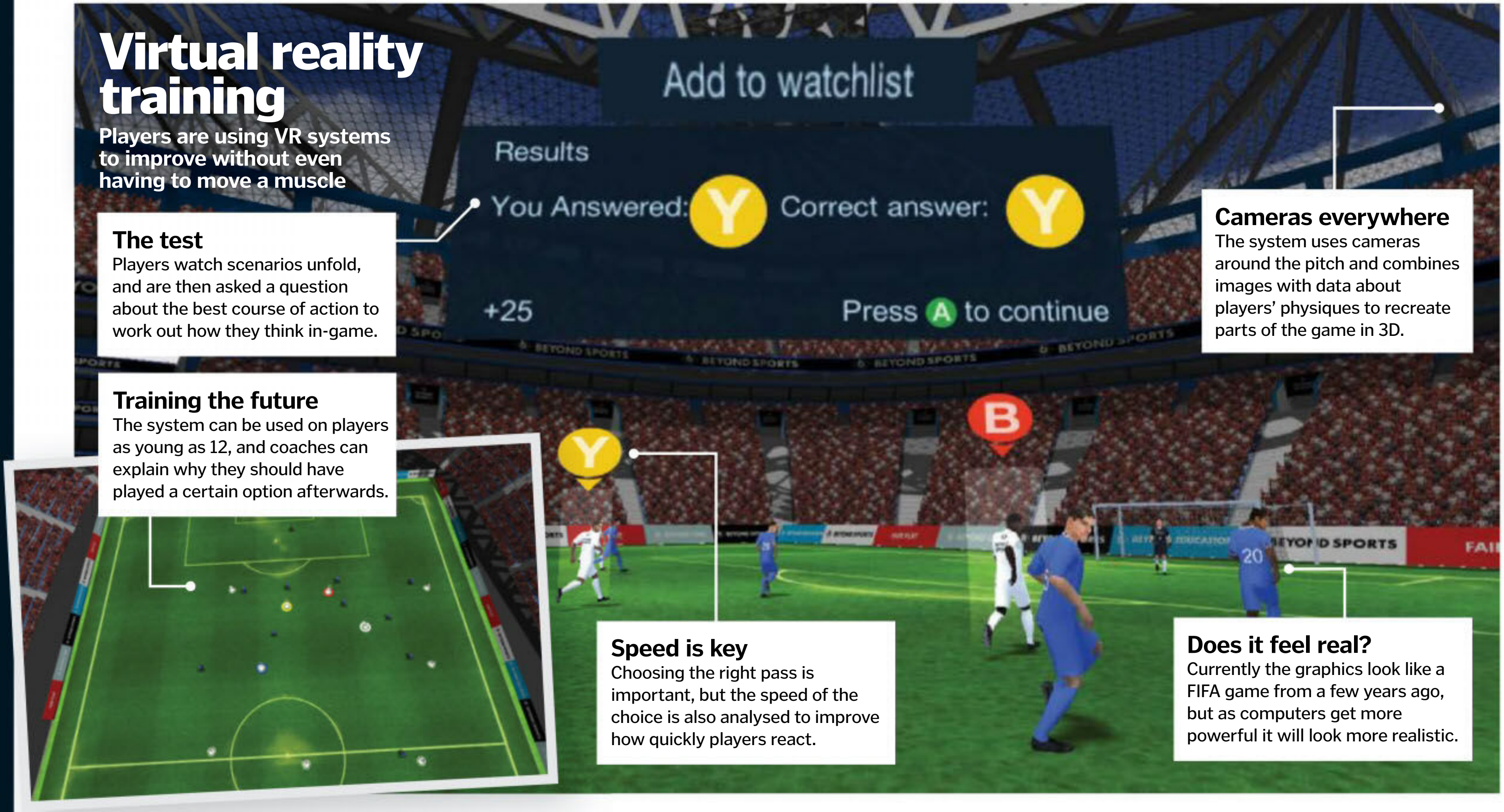
While many of the advancements in the sport over the next few years will certainly be in the stadium, on the pitch and in the homes of fans, some of the biggest changes will actually occur away from the cameras. Training sessions are being transformed as coaches learn more about how athletes' bodies work, as are the ways in which players prepare for their next big match.

New technology, like the Adidas MiCoach smart ball, now allows training sessions to be tracked more closely, and individual aspects of a footballer's game to be closely analysed on the training field. Sensors built into the ball present data about each kick – for example, you can see how hard a shot was struck, follow the flight trajectory, and reveal impact points to help give more insight into how the player is performing. The information feeds straight into a smartphone app via Bluetooth, so players and coaches can instantly see how to get more curl on a free kick, generate more kicking power, or take better penalties.

Individual aspects of a player's game can be closely analysed

Virtual reality training

Players are using VR systems to improve without even having to move a muscle



The test
Players watch scenarios unfold, and are then asked a question about the best course of action to work out how they think in-game.

Training the future
The system can be used on players as young as 12, and coaches can explain why they should have played a certain option afterwards.

Cameras everywhere
The system uses cameras around the pitch and combines images with data about players' physiques to recreate parts of the game in 3D.

Speed is key
Choosing the right pass is important, but the speed of the choice is also analysed to improve how quickly players react.

Does it feel real?
Currently the graphics look like a FIFA game from a few years ago, but as computers get more powerful it will look more realistic.

Q&A Professor David Sumpter reveals the maths behind the match

What are the similarities and differences between maths and football?
At first sight they look very different. One is a game where you kick the ball about and the other is a mental activity. But when you dig a bit deeper, there are real similarities. Maths is not as abstract as we sometimes paint it. Solving applied maths problems involves lots of the spatial thinking and problem solving that confronts footballers. There is also a lot of theory, in terms of formations and tactics, in football and this requires logical thinking very similar to mathematics.

Do footballers actually use maths when training and on the pitch?
They do, and they have done for a long time! I was speaking with ex-Chelsea and Everton player Pat Nevin about this recently. He told me that when he played for Scotland in the 1980s they would plan attacking triangles. So, long before the current interest in data in football, coaches would use mathematical concepts to describe how they wanted their teams to play. What I have found in my research is that a lot of the patterns of play we see on the pitch are mathematically optimised. The positioning of the players uses space efficiently and maximises the chance of a pass being successful.

How can maths help a team win a penalty shootout?
The secret of a good penalty is unpredictability. Of course the striker needs to hit the ball hard and a long way from the keeper, but choosing the side is the difficult part. If you always kick to a random side then

DID YOU KNOW? *Patents filed by major tech companies like Apple show ideas for smartwatch bands that analyse sweat*

Coaches are also focusing on how to get more from the players physically, and modern tech is helping to prolong the fitness of top professionals. In the 2014 World Cup, for example, the England team had coolers filled with drinks, each one tailored to a specific player's needs. Exercise scientists, coaches and nutritionists worked together with experts from a university to create drinks customised for each player, with different electrolytes depending on the amount of fluid that each player lost during the match. In future, kits will likely include sensors that can accurately track a player's physical state, from their temperature to their pulse, and tailored drinks could be made up by machines on the side of the pitch to give them what they need to perform.

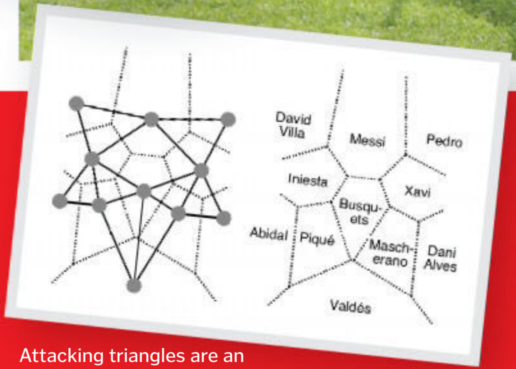
Training sessions are no longer just a place to work on your own game, but to study the opponents' too. Tablet computers are regularly provided to players, which contain notes and videos on specific members of the opposition team. In the future, VR systems may allow players to relive moments in virtual environments to study the movements of opposition players. Technology will, undoubtedly, improve the quality of football in the next few years, as well as the way we watch.

Tracking the action

Technology that tracks a player's status might sound like something we can expect 20 years from now, but thanks to the Viper Pod, it's already here. The device weighs less than 50 grams and is just eight centimetres tall, slipping into the pocket of a custom-made base layer. A built-in GPS module allows the player's position to be tracked without the use of cameras, and the accelerometer and gyroscope can measure acceleration, collisions and more. There's even a heart-rate monitor that reads a player's pulse. The data is sent to a computer, so coaches can see these real-time stats, as well as analyse it later. It's currently used by Manchester United, Barcelona, Juventus and many other teams for training, with more being added to the list all the time. Soon, we may know if that big-name player really is giving 110 per cent!

There are multiple sensors built into the Viper Pod to track a player's movement and body status

© PixelSquid



Attacking triangles are an example of maths in football

the keeper has no way of predicting which way the ball will go.

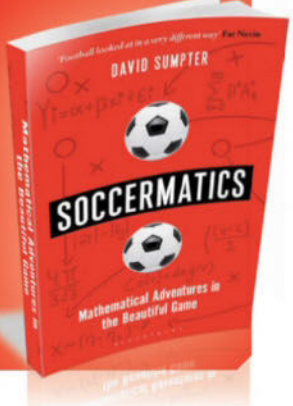
How can maths be used to train footballers?

I think it is an important part of training. Football players are typically intelligent people and it is important to explain to them 'why' some things work on the pitch and why others don't. It is here that maths comes in. It shouldn't be explained so much in equations but in concepts like angle, spin and passing networks.

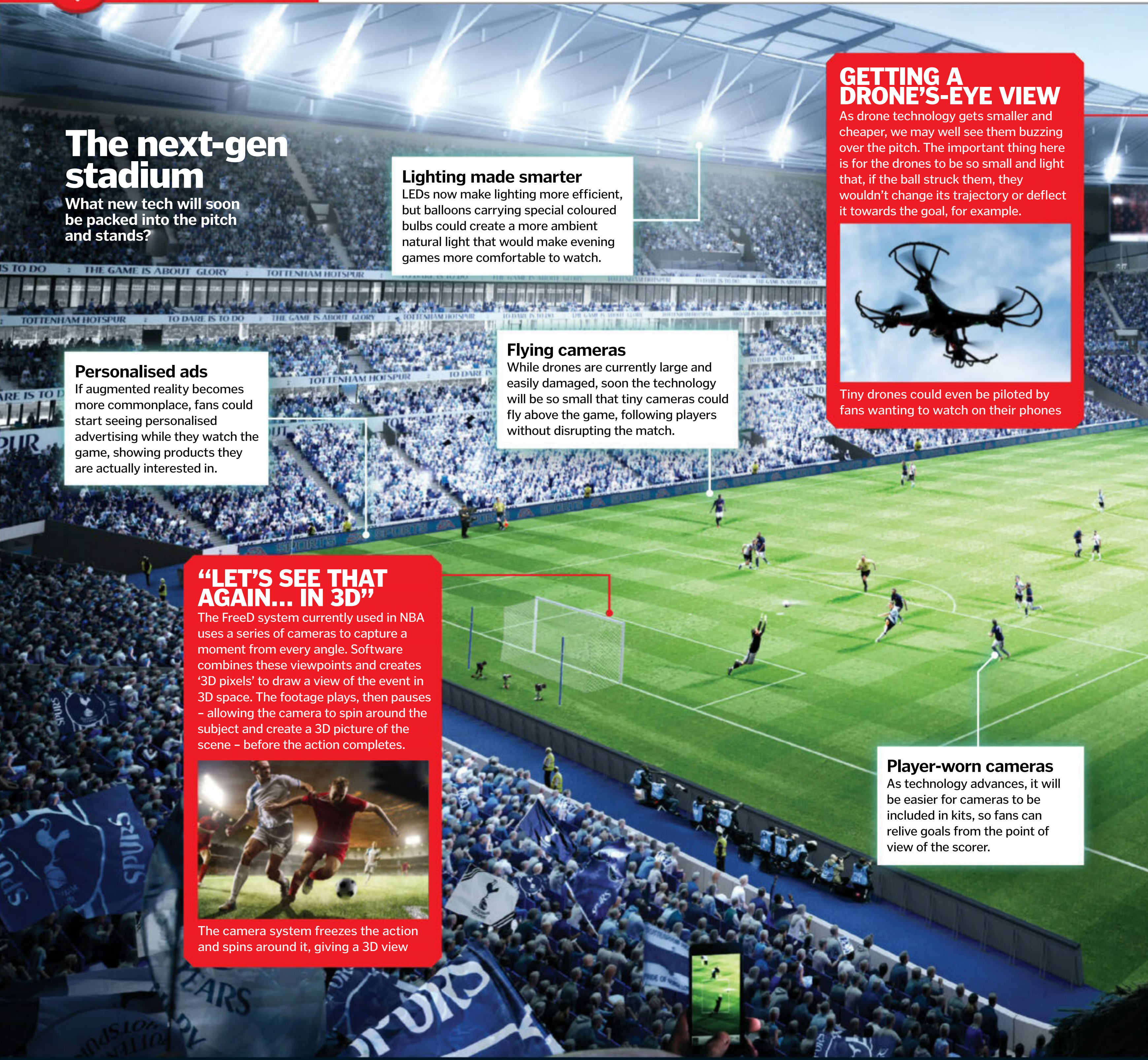
What's your favourite example of football maths?

It's hard to choose! The book is full of them. Here are a few:

- Understanding how the technical staff create half-time maps of the opposition's playing style to identify weaknesses.
- Making player forecasts, comparing how Andrea Pirlo stands in the eye of a storm and how Bastian Schweinsteiger creates a whirlwind.
- Learning about what player stats do and don't tell us, and how teams use them on the transfer market.
- Listening to chants spread through the ground and understanding why songs grow exponentially.



Soccermatics by David Sumpter is out now, published by Bloomsbury



The next-gen stadium

What new tech will soon be packed into the pitch and stands?

Lighting made smarter
LEDs now make lighting more efficient, but balloons carrying special coloured bulbs could create a more ambient natural light that would make evening games more comfortable to watch.

GETTING A DRONE'S-EYE VIEW
As drone technology gets smaller and cheaper, we may well see them buzzing over the pitch. The important thing here is for the drones to be so small and light that, if the ball struck them, they wouldn't change its trajectory or deflect it towards the goal, for example.

Tiny drones could even be piloted by fans wanting to watch on their phones

Personalised ads
If augmented reality becomes more commonplace, fans could start seeing personalised advertising while they watch the game, showing products they are actually interested in.

Flying cameras
While drones are currently large and easily damaged, soon the technology will be so small that tiny cameras could fly above the game, following players without disrupting the match.

"LET'S SEE THAT AGAIN… IN 3D"
The FreeD system currently used in NBA uses a series of cameras to capture a moment from every angle. Software combines these viewpoints and creates '3D pixels' to draw a view of the event in 3D space. The footage plays, then pauses – allowing the camera to spin around the subject and create a 3D picture of the scene – before the action completes.

The camera system freezes the action and spins around it, giving a 3D view

Player-worn cameras
As technology advances, it will be easier for cameras to be included in kits, so fans can relive goals from the point of view of the scorer.

THE TECH-DRIVEN FAN EXPERIENCE

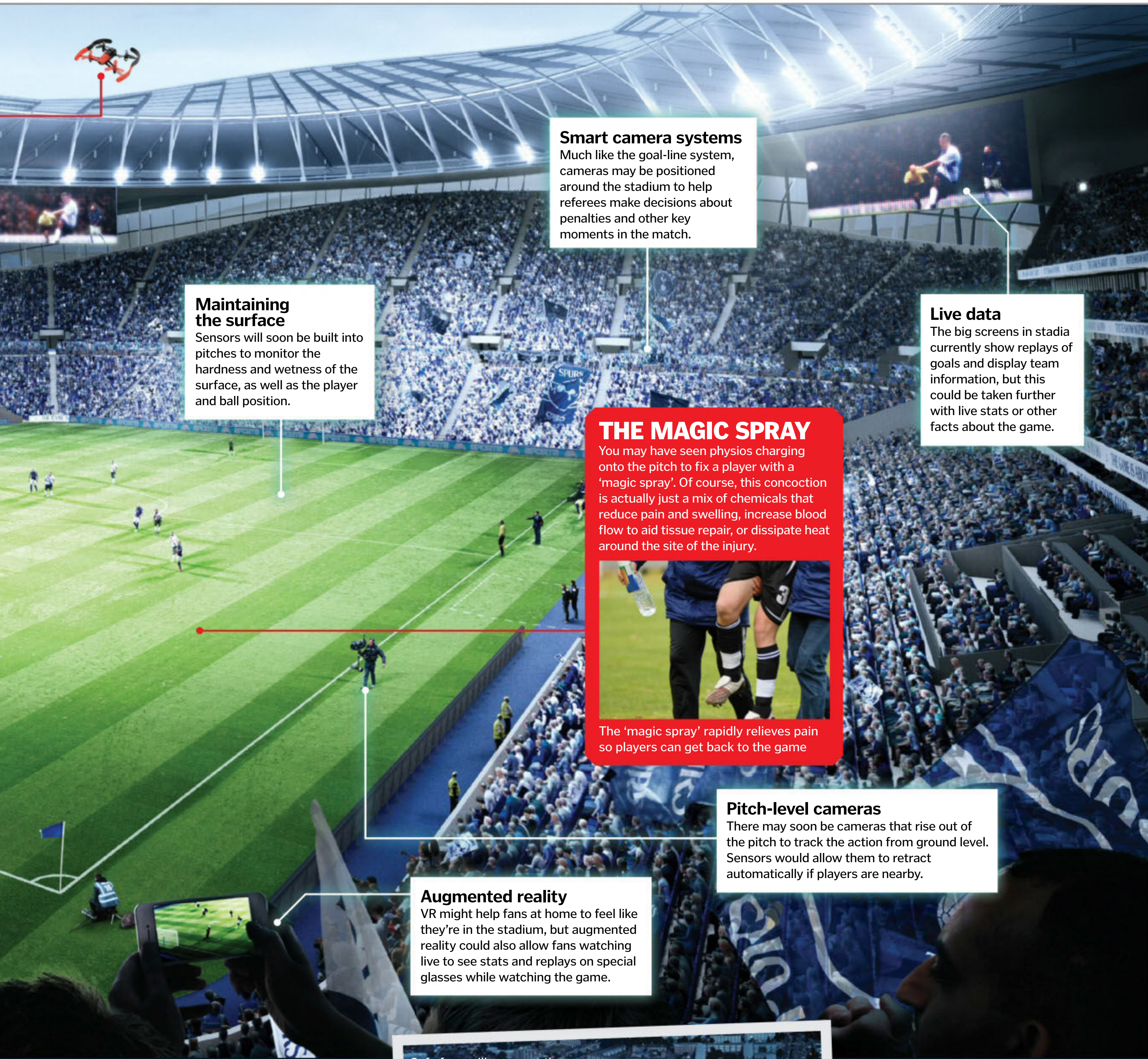
How new advancements will change the way we watch the game

For the moment, there really isn't anything like sitting in the stands with tens of thousands of fans as you cheer for your favourite team. However, in the future, things could be very different. While currently fans pay a premium to watch a game, soon they may be accessible to everyone via the power of VR. Special camera set-ups can now film a full, 360-degree view that records video for VR playback. Soon, these may be used to broadcast games live to VR devices around the world, which would allow you to slip on a headset and watch the game as if you were sitting in the stadium.

Combine these visuals with a specially designed seat that vibrates alongside the chanting, cheering or foot-stamping of the crowd, and a surround-sound headset that records the sound from inside the stadium, and you'd be experiencing something close to what the fans with tickets see and hear.

Even better, with multiple camera rigs around the stadium you could change your seat throughout the game, so you're always behind the goal when your team scores. This

DID YOU KNOW? *The smallest camera-carrying drone measures less than four centimetres across and can stream 420p video*



Maintaining the surface

Sensors will soon be built into pitches to monitor the hardness and wetness of the surface, as well as the player and ball position.

Smart camera systems

Much like the goal-line system, cameras may be positioned around the stadium to help referees make decisions about penalties and other key moments in the match.

Live data

The big screens in stadia currently show replays of goals and display team information, but this could be taken further with live stats or other facts about the game.

THE MAGIC SPRAY

You may have seen physios charging onto the pitch to fix a player with a 'magic spray'. Of course, this concoction is actually just a mix of chemicals that reduce pain and swelling, increase blood flow to aid tissue repair, or dissipate heat around the site of the injury.

The 'magic spray' rapidly relieves pain so players can get back to the game

Pitch-level cameras

There may soon be cameras that rise out of the pitch to track the action from ground level. Sensors would allow them to retract automatically if players are nearby.

Augmented reality

VR might help fans at home to feel like they're in the stadium, but augmented reality could also allow fans watching live to see stats and replays on special glasses while watching the game.

experience may be a few years away, but it's an exciting prospect. Something that will likely happen a little sooner, though, is the addition of detailed player stats for fans, both at home and in the stadium. As sensors like the Viper Pod become smaller and more common, fans can compare the performances of their favourite stars and cheer on the players who are reaching exhaustion, as well as make suggestions for how to change formations or make substitutions based on performance.

Sofa fans will soon get the same experience as those inside the stadium

> "As body sensors become more commonplace, data can be broadcast to fans"

© Populous; Thinkstock

THE FUTURE OF FOOTBALL

How much will the beautiful game have changed by 2050?

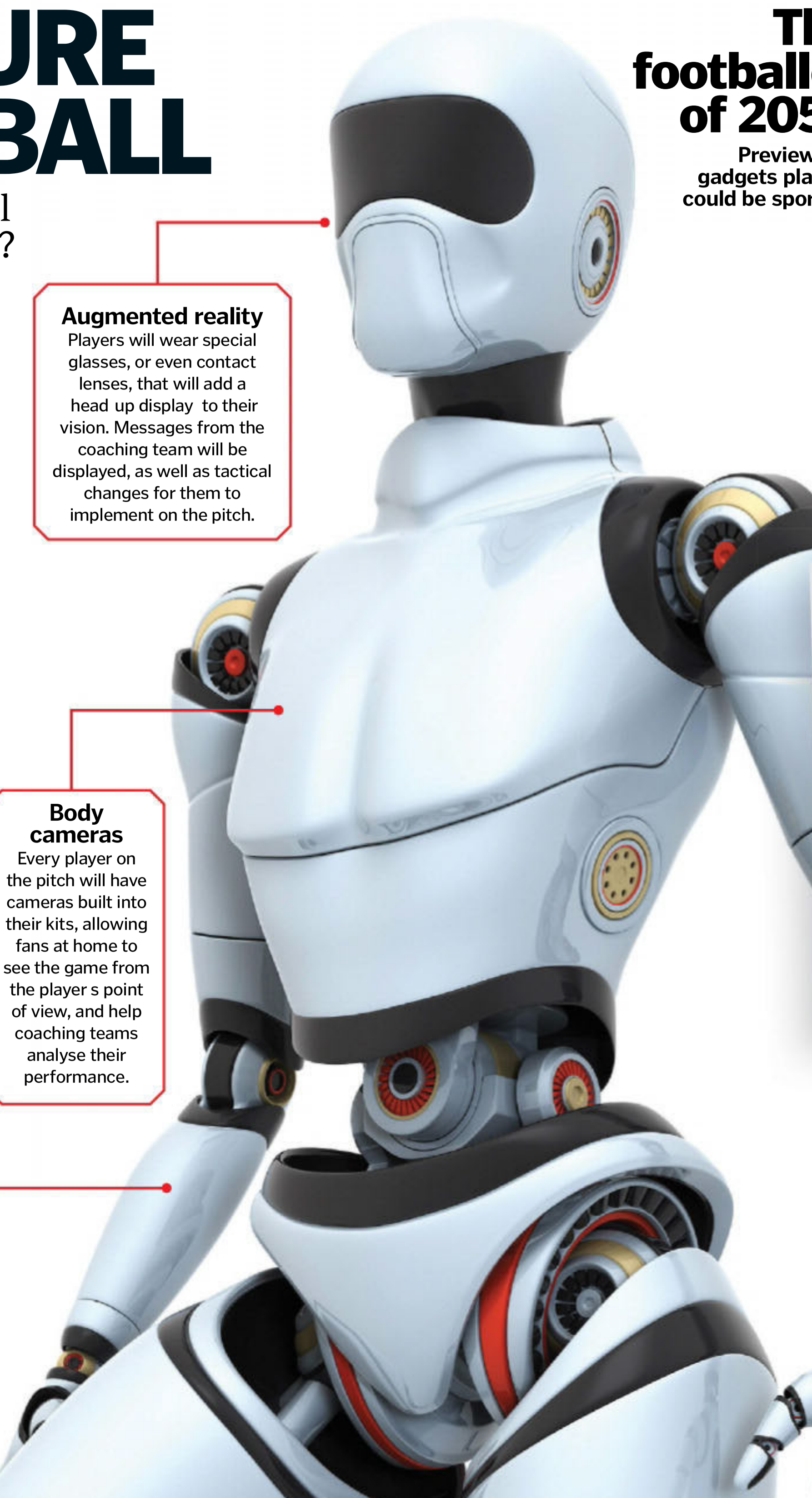
While much of the tech mentioned in this feature is already being developed, or is available right now, we couldn't blow the final whistle without looking a little further into the future of football. By 2050, technological advances will have changed the game that we know and love so that it goes far beyond virtual reality and goal-line sensors.

By then, technology like 'active skin' will allow computers to link to the nervous systems of players. At first, this will be used to track players' physiological data in real-time, but as the technology advances it will become more expansive. When training, a player's movements will be tracked in real-time, and neural stimulation will help players tweak their technique to bring it close to what the computer would consider 'perfect'.

Spectators might be able to watch miniature 3D recreations of games at home on their coffee tables, and they could be in control of the camera angle. But why stop there? Beyond 2050, we could see fans actually controlling the players on the pitch via an android! Excited? You only have 35-50 years to wait…

The footballer of 2050

Preview the gadgets players could be sporting



Augmented reality
Players will wear special glasses, or even contact lenses, that will add a head up display to their vision. Messages from the coaching team will be displayed, as well as tactical changes for them to implement on the pitch.

Body cameras
Every player on the pitch will have cameras built into their kits, allowing fans at home to see the game from the player's point of view, and help coaching teams analyse their performance.

Biometrics
Each player's biometric data will be analysed by sensors either sewn into their kits or embedded in their skin, giving fans and coaches extensive access to stats and player information.

Building the perfect player

If you've ever watched clips from the RoboCup championships with teams of Nao robots shuffling towards a ball and frequently falling over you wouldn't think that android football has any hope of taking the place of the real deal. The goal of RoboCup is to develop an autonomous team of droids capable of beating the top human team by 2050, but the project is still in its early days. With continued advancements in robotics and artificial intelligence, these androids could even be capable of learning from footage of today's legends. A robot that combines Ronaldo's trademark free kicks with Neymar's unbelievable flicks and Messi's close control could well be named humanoid of the match in the 2050 World Cup final.

RONALDO

NEYMAR

MESSI

Future football tech

Robot cameras, holographic replays and more

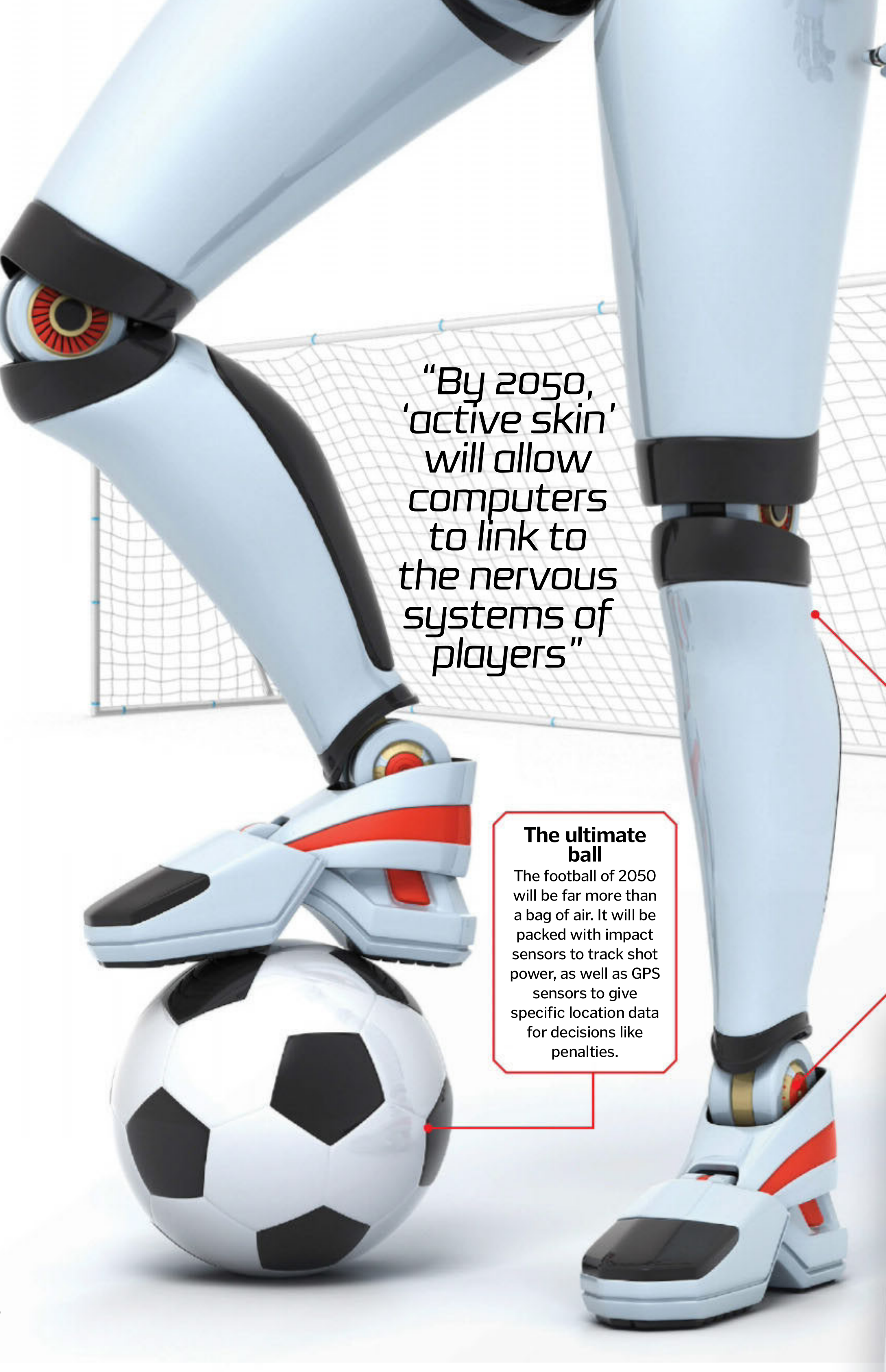
2020s
- Retractable cameras in turf
- Active contact lenses
- Referee augmented reality tools

2030s
- Tiny drone cameras follow players
- 'Active skin' used for health monitoring
- Pitch condition data sensors

2040s
- Real-time player data available
- Audio links to coach allowed
- 3D holographic smartphone replays

2050s
- Sensory simulation – fans 'feel' the game
- Online players compete in 'real' games
- Robot football starts becoming commonplace

2060s
- Fans control android players
- Smart ads based on the fans' physiological data
- Full android leagues set up



> *"By 2050, 'active skin' will allow computers to link to the nervous systems of players"*

Sensory gloves
Sensors built into a goalkeeper's gloves could link to sensors built into a fan's skin, simulating the feel of the ball as they make a save. Combined with VR this would be an incredible experience.

Android players
Fed up of your team losing every week and wish you could control players? That could become reality in 2050 – leagues of human-controlled robots may be ready for kick-off.

Powered-up boots
Accelerometers built into shoes will be commonplace, with live data combining with that captured by the ball to analyse every kick a player makes, both live and after the game.

The ultimate ball
The football of 2050 will be far more than a bag of air. It will be packed with impact sensors to track shot power, as well as GPS sensors to give specific location data for decisions like penalties.

The next-gen football will be packed with cool tech like impact sensors

© Alamy; Nike; Adidas; PixelSquid; SPL

5 REAL-LIFE STAR TREK INVENTIONS

Make it so: How the gadgets on board Starfleet ships 50 years ago inspired modern technology

Scanadu Scout

INSPIRED BY... Tricorder

In the show, Dr McCoy's tricorder could scan a patient's body and instantly diagnose a medical problem. The Qualcomm XPRIZE is a competition to develop a real-life version of this device. One contender is the Scanadu Scout, a tiny scanner that measures your heart rate, blood pressure, core body temperature and other vital signs. Simply holding the Scout to your forehead for ten seconds gives an indication of your health and alerts you to any problems via an accompanying app.

Portable diagnostic scanners could revolutionise healthcare

Mobile phone

INSPIRED BY... Communicator

The Trek technology that's had the biggest influence on reality is the communicator. Starfleet crewmembers used these devices to contact one another, and to transmit emergency signals when in trouble.

While working at Motorola in 1973, Martin Cooper developed the first personal mobile phone, and he later admitted that Captain Kirk's communicator inspired his invention. *Star Trek* communicators were sometimes depicted as wrist devices or even worn as a badge, similar to real-life wearable gadgets like the Apple Watch and the CommBadge.

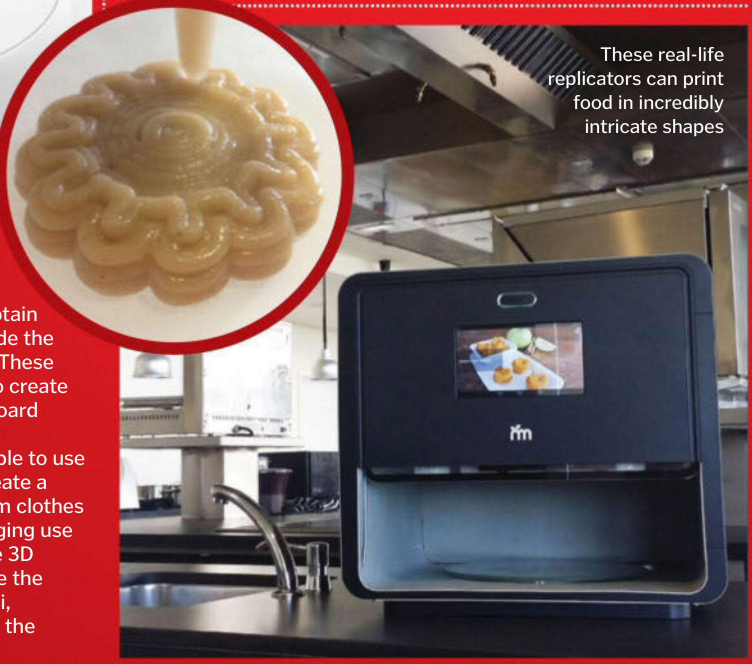
Handheld Communicators bear an uncanny resemblance to flip phones

3D printer

INSPIRED BY... Replicator

"Tea, Earl Grey, hot," said Captain Picard, and the replicator made the drink in a matter of seconds. These fictional devices were used to create meals and other objects on board Federation starships.

In reality, 3D printers are able to use different material 'inks' to create a huge variety of products, from clothes to spacecraft parts. An emerging use of this technology is to create 3D printed food, with printers like the Foodini able to produce ravioli, burgers, biscuits and more at the touch of a button.



These real-life replicators can print food in incredibly intricate shapes

Skype Translator

INSPIRED BY... Universal translator

When you're boldly going where no man has gone before, it helps to understand what the locals are saying. Starfleet crews were given universal translators to seamlessly interpret alien languages.

Microsoft has developed Skype Translator to break down language barriers here on Earth. The program compares your speech to a database of audio snippets in order to compile a transcript. This text is then translated to the desired language and read out by an automated voice.

Skype Translate can convert seven languages during calls

Tablets

INSPIRED BY... PADD

The Personal Access Display Device (PADD) was a hand-held computer used by Starfleet crew. With their sleek design and touchscreen interfaces, these devices are strikingly similar to tablet computers such as the iPad. Tablets have become possible thanks to the miniaturisation of technology. As computer components have got smaller, it has become possible to fit laptop-level hardware into these convenient hand-held gadgets. Tablets' touchscreen designs let users carry out commands with intuitive gestures, like pinch-to-zoom.

By using touchscreen interfaces, PADD props were easier and cheaper to make

© WIKI

EXPLORE THE TECH INSIDE
www.gadgetdaily.xyz

WIN £1,000 ULTRA HD HISENSE SMART TV
Gadget
SELF-FLYING DRONES TAKE OFF!
30 WEARABLE TECH MUST-HAVES
GO PRO WITH ACTION CAMS

Gadget™

Available from all good newsagents and supermarkets

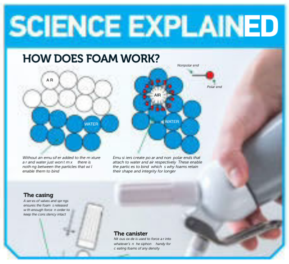
ON SALE NOW
■ 30 WEARABLE MUST-HAVES ■ SELF-FLYING DRONES ■ GOPRO GUIDE

THE COOLEST KIT

TECH TEARDOWNS

BUYING ADVICE

SCIENCE EXPLAINED



HOW TO GUIDES

BUY YOUR ISSUE TODAY
Print edition available at www.imagineshop.co.uk
Digital edition available at www.greatdigitalmags.com

Available on the following platforms
Print Tablet Phone Desktop

facebook.com/gadgetmagdaily twitter.com/xgadget_magazine

Industrial robots

Inside the factories where no one gets tired, sick or even paid

Ninety per cent of all the robots in the world live in factories. The availability of cheap human labour in China and the Far East hasn't slowed down the march of machines, and sales of industrial robots are in fact growing faster in China than anywhere else in the world.

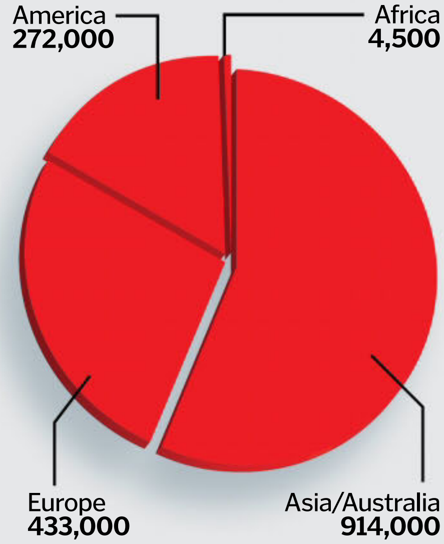
Robots were first put to work in 1961, when General Motors installed Unimate. This was a 1.8-ton, die-cast robot arm that dealt with red-hot, metal car door handles and other parts – dangerous and unpleasant work for humans. Unimate followed instructions stored on a magnetic drum (the forerunner of today's computer hard disks), and could be reprogrammed to do other jobs. When Unimate robots took over the job of welding car bodies in 1969, the GM plant in Ohio was able to build 110 cars an hour – twice as fast as any factory in the world at that time.

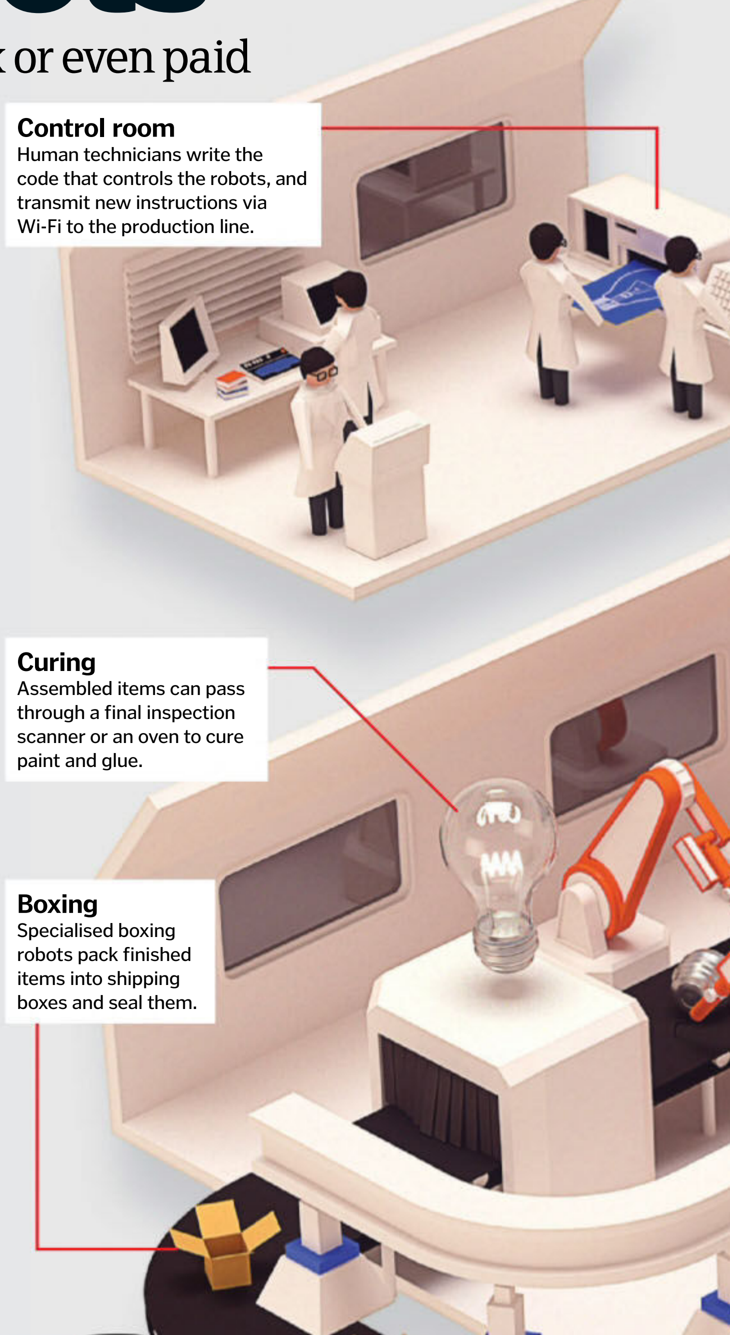
Modern industrial robots have evolved from using clumsy hydraulic pistons to much more precise electric motors for each joint. Sensors on each one detect an LED light shining through a disc with slots cut into it. As the slots interrupt the light beam, they send a series of pulses to the robot's CPU that tells it precisely how far the arm has moved. Cameras mounted on the end of each arm use sophisticated image-processing software that allows them to identify objects, even if they are upside down or rotated on the conveyor belt, while ultrasound proximity sensors prevent the robots from striking obstacles in their path.

Even with all this sophistication, industrial robots are so strong and move so quickly that it has always been dangerous for humans to share an assembly line with them. But the latest machines have joints driven by springs, which are tensioned by motors, instead of motors driving the arm joints directly. This absorbs the force from an accidental knock, and enables the robot to react in time to avoid an injury.

Where do industrial robots live?

Number of robots (as of 2015)





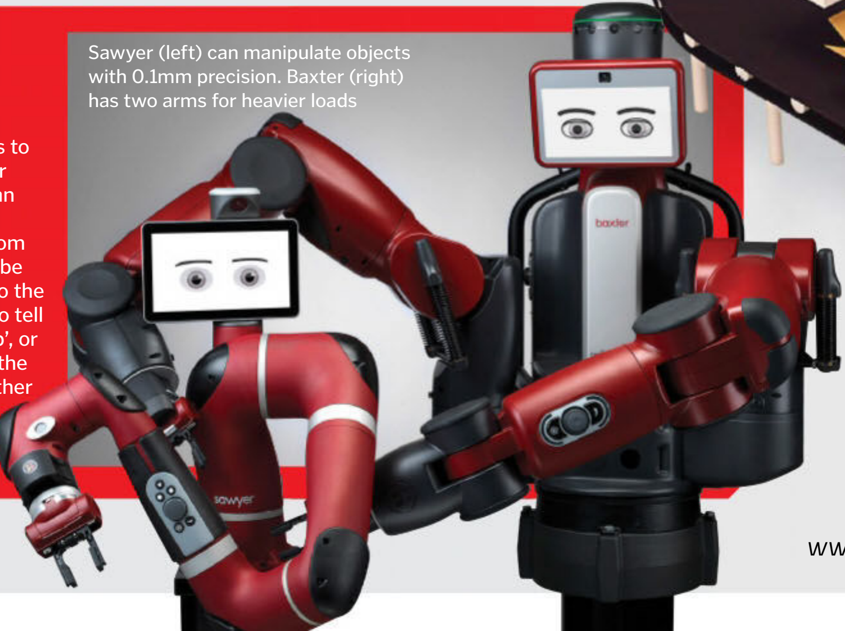
Control room
Human technicians write the code that controls the robots, and transmit new instructions via Wi-Fi to the production line.

Curing
Assembled items can pass through a final inspection scanner or an oven to cure paint and glue.

Boxing
Specialised boxing robots pack finished items into shipping boxes and seal them.

Learning by example

Most industrial robots need programmers to write the complex code that controls their movements, and reprogramming them can involve expensive stoppages. Baxter and Sawyer are a new generation of robots from Rethink Robotics in Boston, US. They can be taught what to do by moving their arms to the right position and then clicking a button to tell them 'this is the thing you need to pick up', or 'place the object in this box'. The face on the display screen allows humans to tell whether the robots are concentrating on learning a new task, working happily or have encountered a problem.

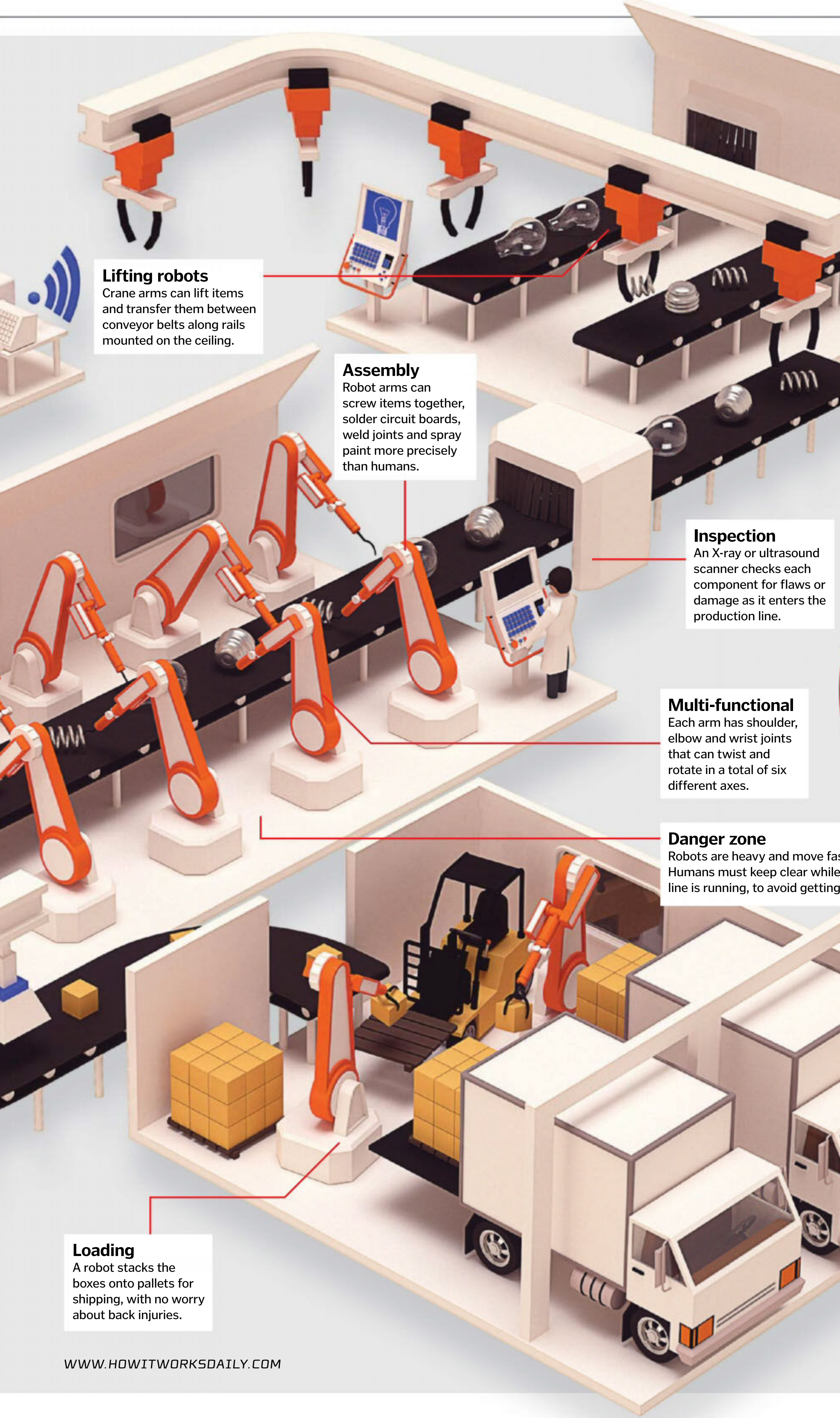


Sawyer (left) can manipulate objects with 0.1mm precision. Baxter (right) has two arms for heavier loads

DID YOU KNOW? *The strongest industrial robot is Germany's KR 1000 1300 Titan PA, which can lift 1,300 kilograms*

A robot assembly line

Robots handle the most stressful and repetitive jobs, while humans supervise



Lifting robots
Crane arms can lift items and transfer them between conveyor belts along rails mounted on the ceiling.

Assembly
Robot arms can screw items together, solder circuit boards, weld joints and spray paint more precisely than humans.

Inspection
An X-ray or ultrasound scanner checks each component for flaws or damage as it enters the production line.

Multi-functional
Each arm has shoulder, elbow and wrist joints that can twist and rotate in a total of six different axes.

Danger zone
Robots are heavy and move fast. Humans must keep clear while the line is running, to avoid getting hit.

Loading
A robot stacks the boxes onto pallets for shipping, with no worry about back injuries.

Joints welded by robots are stronger because they are more precise and consistent

© WIKI; Illustration by Nicholas Forder

Making medical tablets

The process of turning powder into pills

Pharmaceutical companies use machines called tablet presses to transform powders into tablets. To start, the powdered material is fed into a hopper and flows through housing into a die that holds a small amount of powder. The die lies between two punches that will press the powder into shape. The lower punch drops down, allowing the granules to fill the space to the exact measurement needed for the type of tablet.

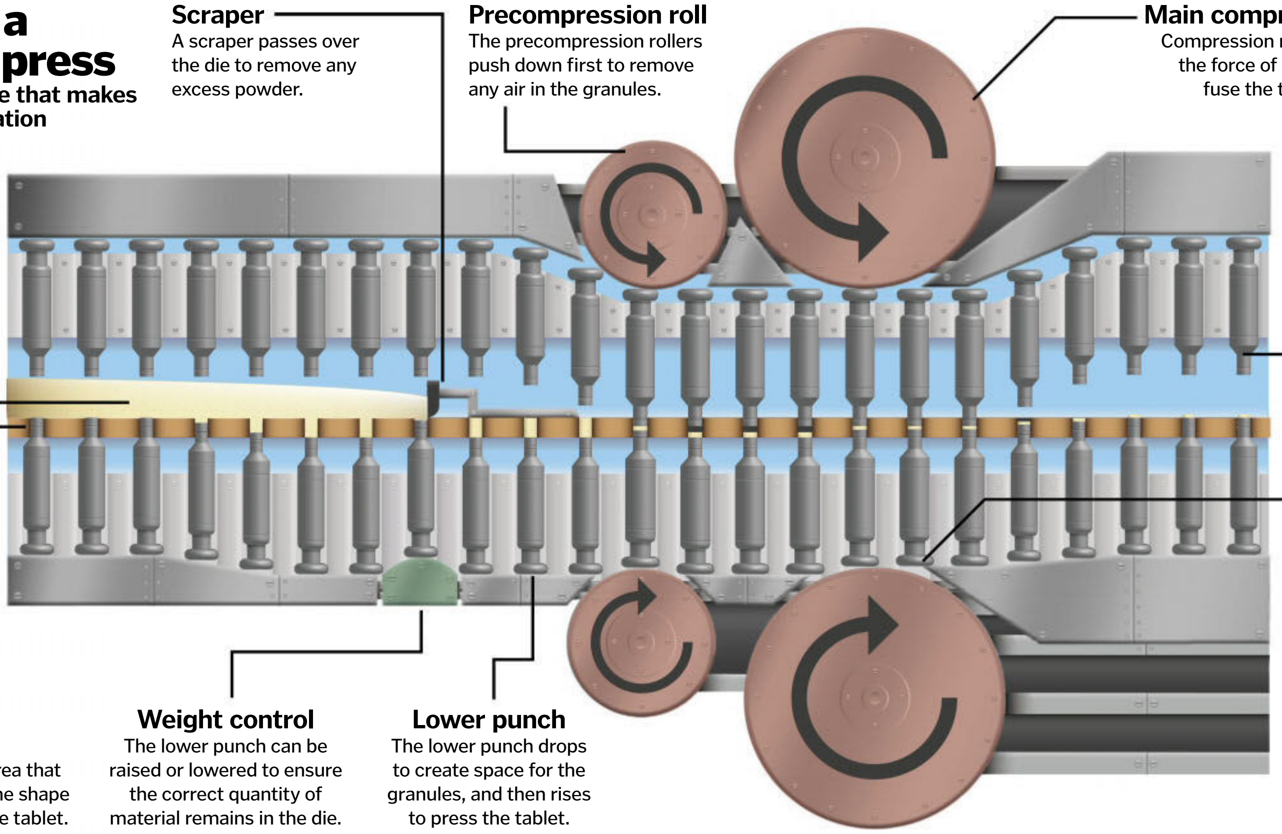
A scraper then removes any excess and the upper and lower punches then compress together; first at low pressure to remove any excess air in the powder, then at higher pressure to form the tablet.

The size and shape of the dies and punches are different for each medication so that companies can create unique shapes, as well as stamp their brand name into the pills. Once the tablet is pressed, the upper punch raises and the lower punch ejects the tablet, which goes down a chute to be collected. Each tablet press contains numerous individual stations, allowing for the production of hundreds of thousands of tablets every hour.

High-speed machines use force to mould tablets

Inside a tablet press

The machine that makes your medication



Scraper
A scraper passes over the die to remove any excess powder.

Precompression roll
The precompression rollers push down first to remove any air in the granules.

Main compression roll
Compression rollers increase the force of the punches to fuse the tablet together.

Feeder
This directs the granules for the drugs into the die.

Upper punch
The upper punch moves down to press the tablet and up to help release it.

Ejection
The lower punch is raised as it passes over the ejection cam, and the pill is popped out of the die.

Die
This is the area that determines the shape and size of the tablet.

Weight control
The lower punch can be raised or lowered to ensure the correct quantity of material remains in the die.

Lower punch
The lower punch drops to create space for the granules, and then rises to press the tablet.

Pedestrian crossings

Do these buttons really do anything? Stop, look, learn…

The wait for the red man (or hand, depending on where you live) to turn green so you can cross the street can seem like an eternity. Some people even press the button repeatedly, hoping to speed things up. The truth is that depending on the type of junction, where it's located, and the time of day, the button might not be doing anything at all.

In theory, the button is connected to the traffic light at the intersection of a major road and a minor road. When pressed, the light on the major road changes from green to red within around 90 seconds, allowing the pedestrian to cross. However, sometimes the button is rendered useless; the walk signal will appear anyway in a prescribed amount of time because it's programmed to the signal patterns.

A press of the button is usually required at standalone pedestrian crossings, and some junctions will vary whether the pattern is affected by the button or not, depending on the time of day. However, some people argue that defunct buttons still exist at junctions to discourage people from ignoring the lights.

Pushing the button may or may not influence when the green man appears

© Thinkstock; Illustration by The Art Agency

Special offer for readers in ***North America***

5 issues FREE

When you subscribe*

“The action-packed science and technology magazine that feeds minds”

WHY YOU'RE AFRAID OF THE DARK
HOW IT WORKS
SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE
THE SCIENCE OF FOOTBALL
THE TECH & TACTICS BEHIND TOP TEAMS
INTERSTELLAR SPACE TRAVEL
How we will sail to the stars at 100 million mph
ANIMAL INVASION
The places on Earth where critters have taken over
DESIGNED FOR STEALTH & SPEED
STAR TREK GADGETS that actually exist
NUCLEAR REACTORS
DEADLY WEAPONS
SEEK & DESTROY
SUPER SUBMARINES
THE INCREDIBLE TECH POWERING THE WAR BENEATH THE WAVES
JOURNEY TO JUPITER
Everything you need to know about NASA's JUNO mission
+ LEARN ABOUT
LIGHTHOUSE LENSES
VICTORIAN SURGERY
DYSON HAIR DRYER
BEACH CLEANERS
AIRBUS JETLINERS
ANCIENT BURIALS
PETROL STATIONS
TRAIN DRIVERS
FIGS & WASPS
BIRD EGGS
AVOCADOS
CLOUDS
www.howitworksdaily.com
ISSUE 87
£4.25

Order hotline **+44 (0)1795 418 680**

Online at **www.imaginesubs.co.uk/hiw**

Quote **USA** for this exclusive offer!

***Terms and conditions** This is a US subscription offer. You will actually be charged £53 sterling for an annual subscription. This is equivalent to $80 at the time of writing, exchange rate may vary. 5 free issues refers to the USA newsstand price of $9.99 for 13 issues being $129.87, compared with $80 for a subscription. Your subscription starts from the next available issue and will run for 13 issues. This offer expires 30 September 2016.

The Dyson Supersonic has three different nozzles, which attach magnetically for easy adjustments

The Dyson Supersonic

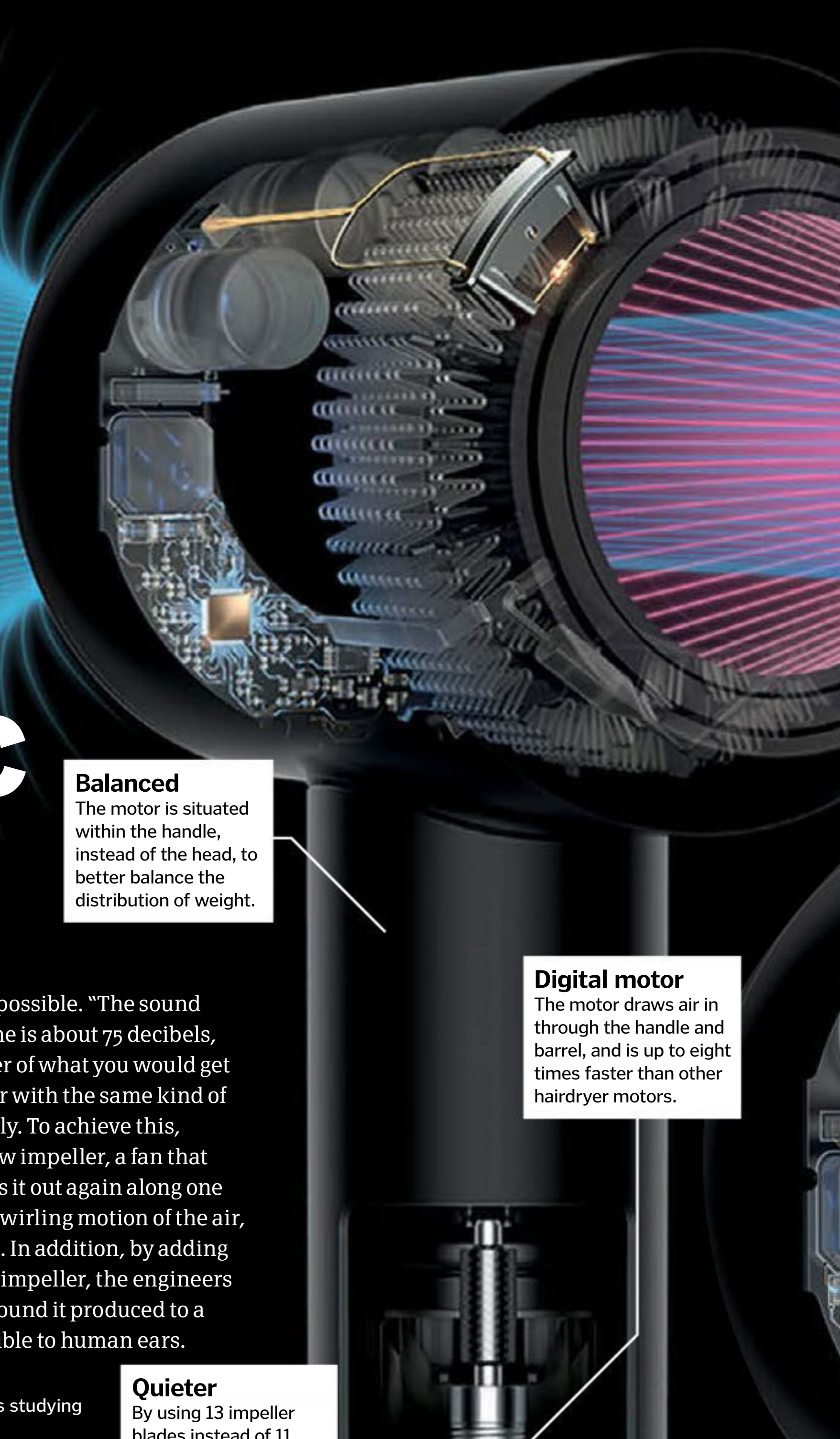
From the vacuum cleaner company comes its first-ever hair dryer, designed to be quiet and lightweight

Dyson has applied its engineering know-how to reinvent the hair dryer, and the result is the Dyson Supersonic – a new type of device that is lighter, quieter and better for your hair. The company has invested £50 million ($72 million) into the development of the hair dryer, which was designed in a state-of-the-art laboratory dedicated to studying the science of hair.

"When your hair is heated above a certain temperature, it will start to change its structure in a way that can't be reversed," says Matt Kelly, a mechanical engineer at Dyson. "This happens above 150 degrees Celsius, but some hair dryers can get into the region of 200 degrees Celsius, which is far too hot." At these extreme temperatures, small holes can appear in the strands and cause light bouncing off of your hair to scatter, making it look dull. To protect your hair's natural shine, the Dyson Supersonic constantly measures the temperature of the air flowing out of the nozzle, and feeds this information to a microprocessor. This then controls the level of heat so that it never exceeds a certain limit.

The other major problem with conventional hair dryers is the noise they produce, so Dyson set out to make the Supersonic as quiet as possible. "The sound power from the machine is about 75 decibels, which is about a quarter of what you would get from another hair dryer with the same kind of performance," says Kelly. To achieve this, Dyson used an axial flow impeller, a fan that draws air in and pushes it out again along one axis. This reduces the swirling motion of the air, thereby reducing noise. In addition, by adding two extra blades to the impeller, the engineers were able to push the sound it produced to a frequency that's inaudible to human ears.

Dyson's hair lab spent years studying the science of shiny locks



Balanced
The motor is situated within the handle, instead of the head, to better balance the distribution of weight.

Digital motor
The motor draws air in through the handle and barrel, and is up to eight times faster than other hairdryer motors.

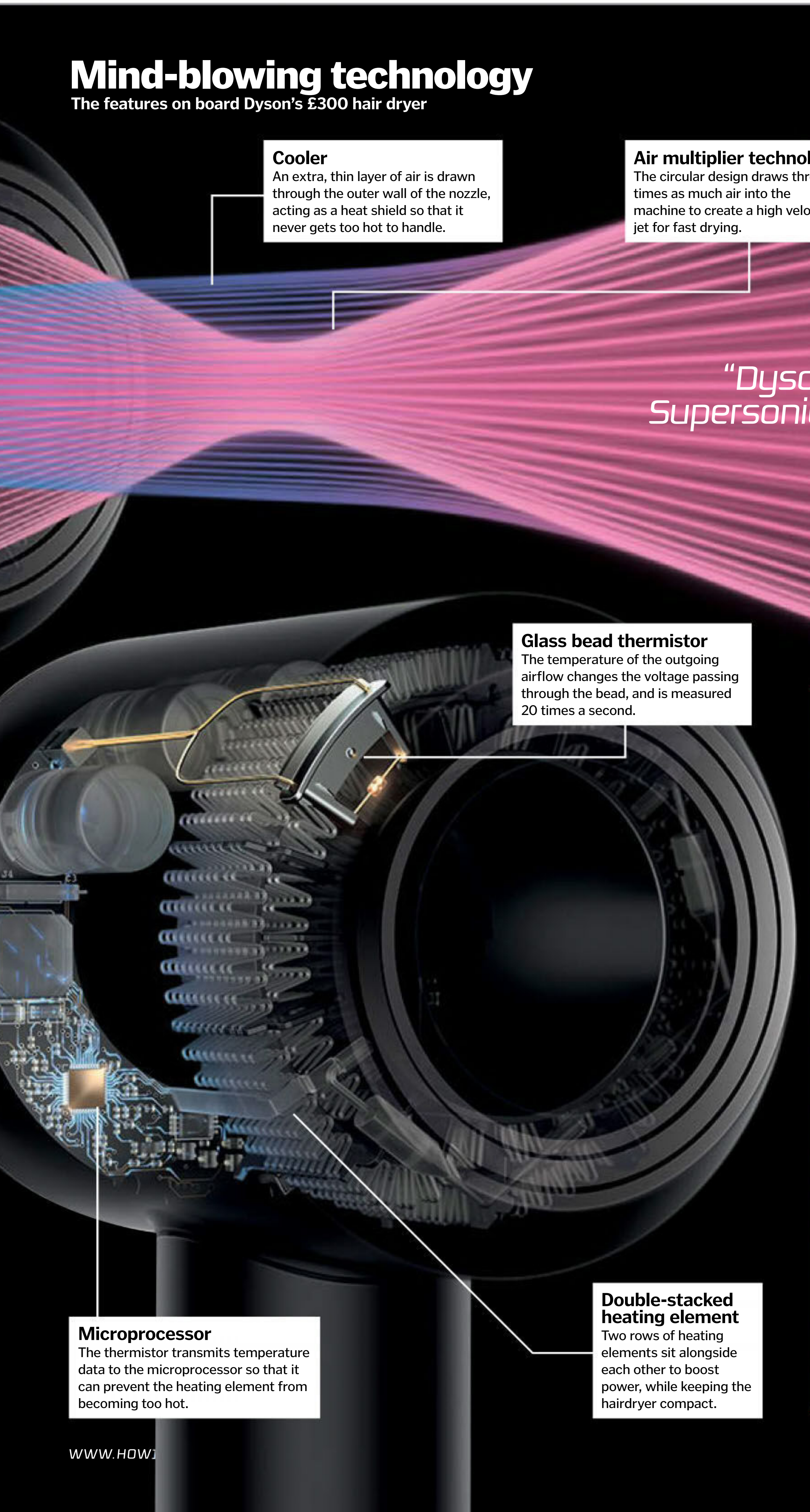
Quieter
By using 13 impeller blades instead of 11, the frequency of sound produced is pushed beyond the audible range for humans.

Axial flow impeller
This fan is designed to smooth the flow of air so it travels in one direction, reducing turbulence and therefore noise.

DID YOU KNOW? *Most hair dryers are tested on pieces of wet cloth, but Dyson used over 1,600 kilometres of real human hair*

Mind-blowing technology

The features on board Dyson's £300 hair dryer



Cooler
An extra, thin layer of air is drawn through the outer wall of the nozzle, acting as a heat shield so that it never gets too hot to handle.

Air multiplier technology
The circular design draws three times as much air into the machine to create a high velocity jet for fast drying.

Glass bead thermistor
The temperature of the outgoing airflow changes the voltage passing through the bead, and is measured 20 times a second.

Microprocessor
The thermistor transmits temperature data to the microprocessor so that it can prevent the heating element from becoming too hot.

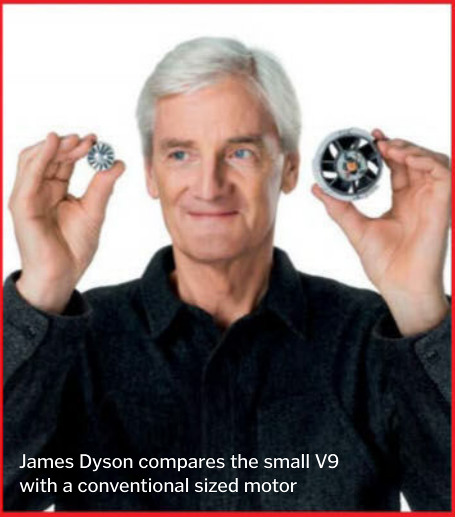
Double-stacked heating element
Two rows of heating elements sit alongside each other to boost power, while keeping the hairdryer compact.

> *"Dyson set out to make the Supersonic as quiet as possible"*

Motor magic

The reason most hairdryers are bulky and uncomfortable to use for long periods of time is because the motor is located in the head, making them top heavy. To solve this problem, Dyson has created its smallest, lightest digital motor yet, the V9. Created by a team of more than 15 motor engineers, the V9 is just 27 millimetres wide, and spins 110,000 times per minute, allowing it to draw in more air for a more powerful performance.

Its small size means that it can be fitted inside the handle of the hairdryer, bringing the centre of mass closer to your hand for a more balanced hold. This also means that Dyson has been able to make the barrel of the device shorter, enabling you to hold it closer to your head, putting less strain on your arm.



James Dyson compares the small V9 with a conventional sized motor

© Dyson

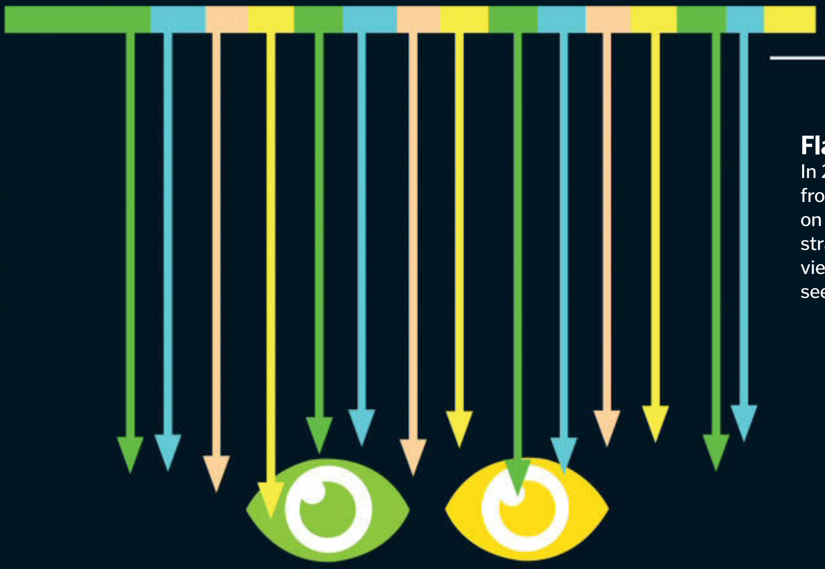
3D without glasses

Throw away those specs and immerse yourself in a 3D movie at home

With more and more 3D content heading our way, 3D TVs are the latest must-have in home entertainment. However, there's one big disadvantage; most people don't want to wear a pair of chunky 3D glasses while sitting in their living room. Unfortunately, without the glasses, the picture is just a blur, as they are needed to filter the light that reaches the viewer's eyes so that each one sees a different image.

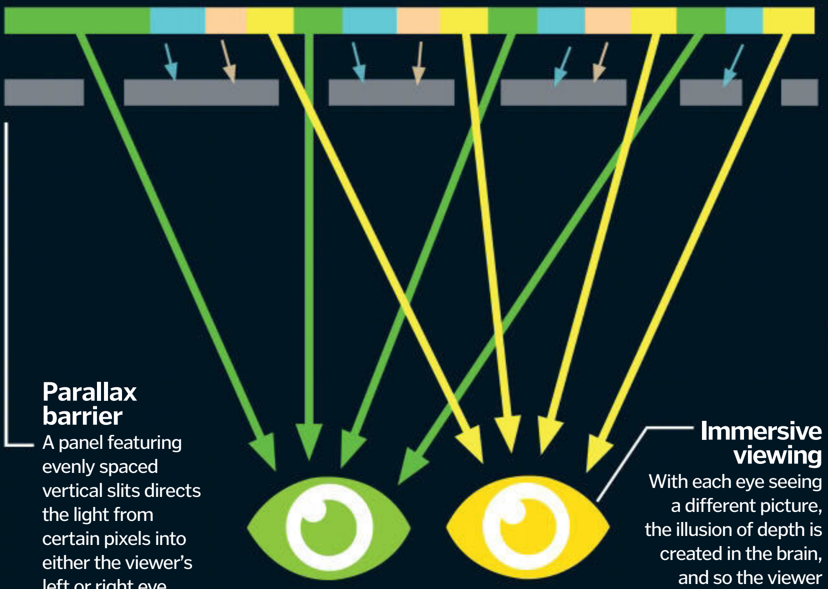
Now though, TV manufacturers are experimenting with glasses-free 3D, which uses a technique known as autostereoscopy. A parallax barrier is placed in front of the screen to direct a different image to each of the viewer's eyes. For 2D content, the barrier can be deactivated, but at the touch of a button the picture can be made to jump out at you on the sofa. Normally for this to work, the viewer would need to sit in a 'sweet spot' directly in front of the screen, but software can be used to form strips of images, creating additional viewing points, so multiple people can enjoy the 3D action together.

2D viewing



Flat image
In 2D mode, light from all of the pixels on the screen travel straight to the viewer, so each eye sees the same view.

3D viewing



Parallax barrier
A panel featuring evenly spaced vertical slits directs the light from certain pixels into either the viewer's left or right eye.

Immersive viewing
With each eye seeing a different picture, the illusion of depth is created in the brain, and so the viewer sees a 3D image.

How juicers work

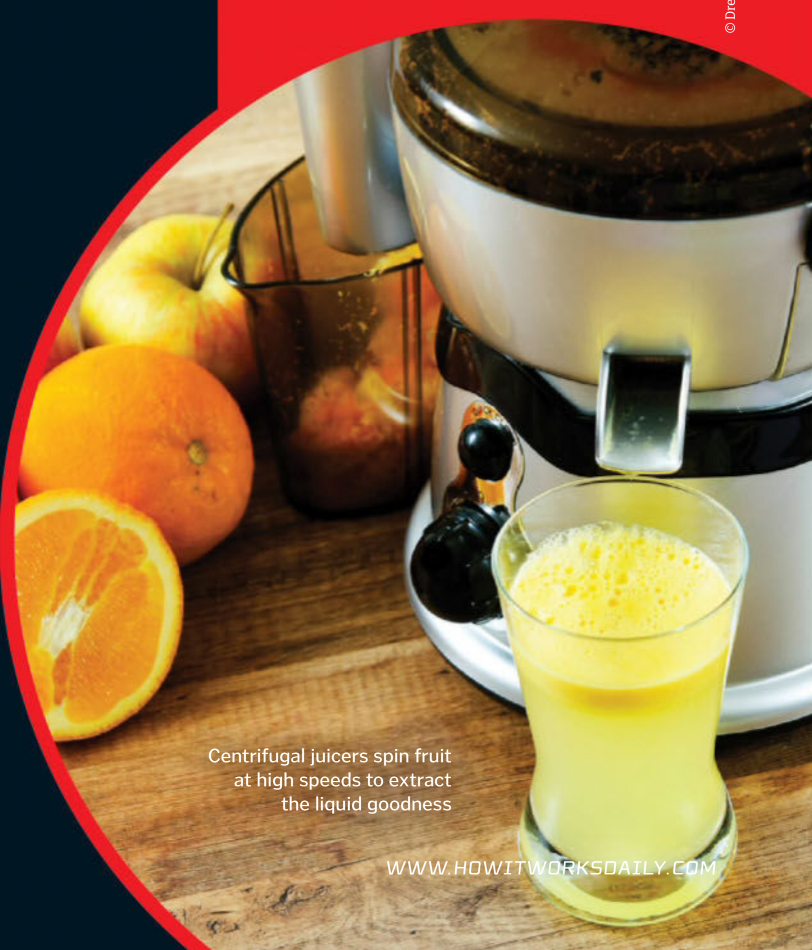
The machines that can turn the contents of your fruit bowl into a refreshing drink

There are a few different types of juicer you can buy for your kitchen. Some use a corkscrew-like device to squeeze the juice from the fruit, but the most common are centrifugal juicers, which work through spinning.

When the fruit is pushed through the feed tube at the top, it falls into a basket, which acts as a centrifuge. A centrifuge is any machine that spins its contents in one continuous direction, and the ones found in juicers can spin at over 97 kilometres per hour. An electric motor spins the basket, which has a grater at the bottom to chop the fruit into smaller pieces.

As the fruit spins, inertia and centrifugal force push it up against the basket wall, which features lots of tiny little holes. The spinning motion forces the liquid from the fruit though these holes, and it collects in the juice container, ready to drink. Meanwhile, the remaining pulp is forced up and over the edges of the basket, where it falls into a waste container, ready to be thrown away.

© Dreamstime



Centrifugal juicers spin fruit at high speeds to extract the liquid goodness

DMRLS
Collectables & Curios

www.dmrls.co.uk

15% off first order
Use promotional code at checkout
HIW616
Valid until 30/07/2016

Email: info@dmrls.co.uk

To advertise in

HOW IT WORKS

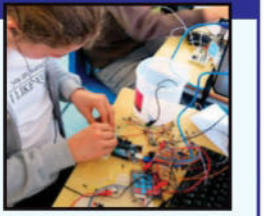
Contact us on 01202 586442

adinfo@imagine-publishing.co.uk

Exclusive Senior (Age 13+) Courses ...

Build & Fly Your Own Quadcopter and Explore Systems Control Theory

Learn C Programming Whilst Constructing Your Own Robot Arm



Build Laser Projectors and Games and Learn Arduino Coding in Inventor School

Exclusive Junior (Age 9-12) Courses ...

Build Your Own Precision WiFi Drawing Robot and Learn How to Code

Learn Rocket Physics as You Build Rockets and an Electronic Launcher

Learn Coding & Build Laser Trip Wires, Alarms and More in Inventor School

Open Courses ...

Build a WiFi Laser Tag System with a Smartphone Control App & Learn Programming Whilst you 'Hack' The Code

Learn Coding, Graphics, Sound Effects, Music Production & More Whilst Designing Your Own Games

Want to Know More?

Tech Camp is the UK's original camp of its kind and remains the only one specialising in teaching coding through advanced take-home projects. It's perfect for creative youngsters who like making things (or taking them apart!) or to show those who are forever playing games how to start designing their own.

We have tutors from the likes of Cambridge & Imperial, maximum groups of eight, and exclusive courses not available anywhere else.

Come as a day camper or join hundreds of other young people from around the UK at our flagship residential camps where you have your own en-suite room and spend evenings playing laser tag, disassembling electronics and much more.

techcamp.org.uk
Inspiring Tomorrow's Inventors

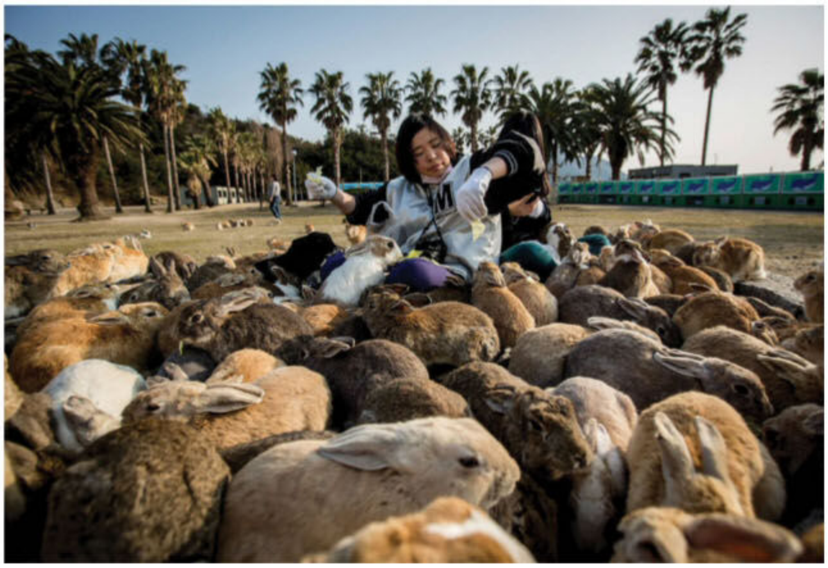
www.techcamp.org.uk info@techcamp.org.uk 0118 380 5678

To advertise here contact us on 01202 586442

Animal invasions

Humans may think they rule the world, but what happens when the animals take over?

Okunoshima is now a popular tourist attraction for those in search of a bunny bundle



Rabbit Island

Okunoshima, Japan

Being chased by a herd of hungry rabbits sounds like a bizarre dream, but it's all part of the experience for visitors to the small Japanese island of Okunoshima.

Hundreds of bunnies live on the island, but how they got there in the first place is a mystery. The leading theories are that the bunnies' ancestors were escapee lab rabbits from the island's World War II poison gas factory, or they were pet rabbits released by schoolchildren in the 1970s.

With no natural predators on the island, and rabbits' notorious breeding rate, the bunny population has boomed. Mature females can produce a new litter of kits every month, and it is estimated that in just three years, one mother and her offspring can produce 50,000 rabbits. While this number seems high, rabbits are top of the menu for many predators, and as such up to 80 per cent of baby bunnies are usually killed shortly after leaving the nest. Without this predator-prey balance, Okunoshima has become home to rabbit swarms. What's also unusual is how bold the bunnies are. Wild rabbits are typically timid and will scamper back to their burrows at the first sign of a threat. Okunoshima's tame rabbits readily chase down visitors for one reason: food. Such a high population means that natural vegetation on the island gets eaten up quickly. Tourists bringing snacks are just another source of food for these fluffy fiends.

{ Cat Islands }
Japan

It is estimated that cats outnumber humans by a ratio of six-to-one on Aoshima, Japan. These feral felines were originally brought to the island to help control rodent populations on fishing boats. With no predators on the island, and only some of the cats neutered, the moggy population kept growing.

Aoshima is one of several 'Cat Islands' in Japan. Another example is Tashirojima, where cats were introduced to protect the island's silk industry. Tashirojima's silkworms were vulnerable to pests such as mice, and cats were very efficient at keeping the rodents at bay. Many locals and tourists believe that feeding and caring for the cats brings good luck, so they are rarely short of a meal.

Nicknamed Cat Heaven, Ainoshima is another feline-flooded island. This name is misleading, as the life of a wild island cat is by no means heavenly. Scientists studying their behaviour found that these animals are highly territorial, and live for just three to five years – around a decade less than their domestic counterparts.

Some believe that feeding the islands' cats brings good fortune

Scientists observed the cats on Ainoshima forming gangs

> "These feral felines were brought to the island to control rodent populations"

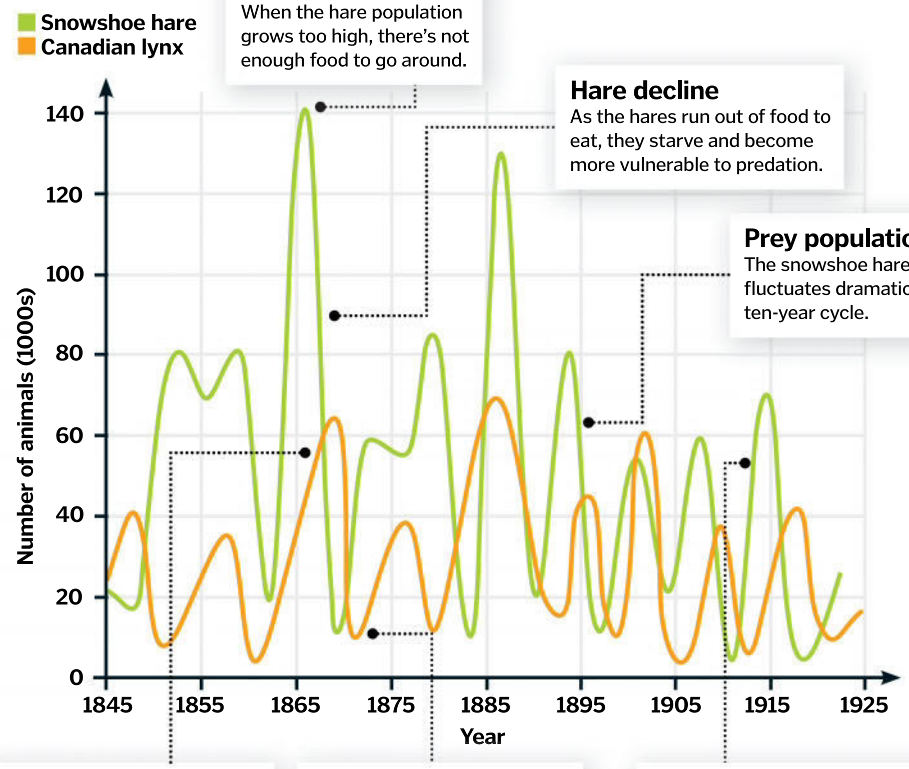
The predator-prey dynamic

How this delicate balance influences population

Everything in an ecosystem is interconnected, and any disruptions within a food chain will impact the other species involved. The interdependence between predators and their prey is one example of the importance of this fragile equilibrium.

One of the most well-studied predator-prey relationships is that of the Canadian lynx and its favourite prey, the snowshoe hare. Populations of the snowshoe hare follow a fairly regular cycle every decade or so. At the cycle's maximum, there can be as many as 1,500 snowshoe hares per square kilometre – a population density that the environment can't sustain. As the hares begin to starve they become weaker and easier for their predators to catch. In the short term, the lynxes have more food, so they are more likely to survive and their numbers increase.

Eventually, as the number of hares declines, lynxes struggle to find alternative prey to fulfil their energy needs, so their populations also fall. The hares that do survive then face less competition for food as vegetation regrows, and low lynx numbers means a reduced threat of predation. Hares breed quickly so the population rises rapidly, starting the cycle all over again.



Population peak
When the hare population grows too high, there's not enough food to go around.

Hare decline
As the hares run out of food to eat, they starve and become more vulnerable to predation.

Prey population
The snowshoe hare population fluctuates dramatically in each ten-year cycle.

Predator population
Hares form the majority of a lynx's diet, so their population levels are closely linked.

Lynx decline
The lynx population declines around two years after the hare's, as they run out of prey.

Rising populations
As vegetation grows, so does the hare population, providing more food for lynxes.

© Alamy; Getty

Pig Beach
The Bahamas

Visitors to the uninhabited island of Big Major Cay in the Bahamas are met with a strange sight. Around 20 pigs live on the beach and are partial to a quick swim around the bay. It is thought that the pigs' ancestors were left on the island by sailors, who intended to return and cook them, or alternatively, that they escaped from a nearby shipwreck. Although they are surrounded by salt water, there are several freshwater springs on the island for them to drink. In recent years, the island has become a popular tourist destination for those who want to take a dip with these beach Babes.

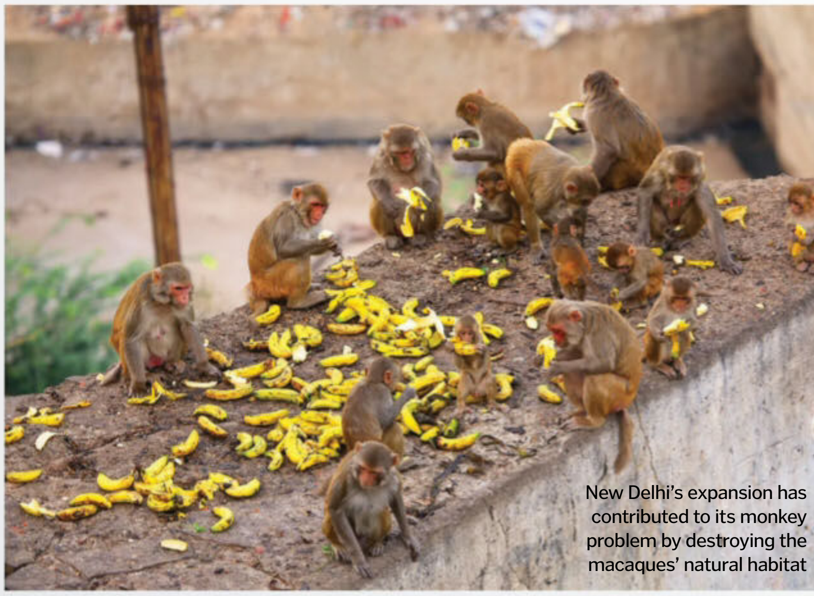
The island's feral pigs are quite tame, and will snaffle any snacks that tourists bring them

The pigs of Big Major Cay often paddle up to tourist boats, expecting treats

Monkey mayhem
New Delhi, India

Thousands of wild macaques roam the streets of New Delhi, causing havoc as they search for food. The problematic primates trash homes and offices, ride public transport and have even invaded the city's parliament buildings. New Delhi's Hindu residents often feed and protect the macaques, as they consider these monkeys to be sacred. This encourages more monkeys to the area, which can be dangerous as they have been known to bite humans, and many carry rabies.

Delhi officials have come up with an innovative solution to help scare the monkeys off. They employ a team of people to shoo the pesky primates away from buildings by impersonating langur monkeys, which the macaques are afraid of.



New Delhi's expansion has contributed to its monkey problem by destroying the macaques' natural habitat

Crab chaos
Christmas Island, Australia

Over 120 million red crabs live in Christmas Island's central rainforests. For most of the year they don't stray far from their burrows, but when the wet season begins, they take over the island. Roads close and barriers and bridges are put in place to allow these crowds of crustaceans to migrate safely.

Mature crabs travel from the rainforest to the shore in order to breed. Females lay their eggs into the sea, where they hatch immediately. The baby crabs spend one month maturing before leaving the water. After around four years of growth, they will join the mass migration and travel to their ancestral rainforest home.

The crabs migrate back to the rainforest after breeding at the shoreline

Roads and bridges are closed to allow for the crabs to migrate safely

DID YOU KNOW? *They may look cute, but Delhi's monkeys bit over 1,800 people in 2015*

House mice prey on the vulnerable ground nests of Gough Island's birds

The remote island is home to endangered seabird species, like the northern rockhopper penguin

Killer mice

Gough Island, South Atlantic Ocean

In the middle of the South Atlantic Ocean, between Argentina and South Africa, lies Gough Island. This British territory and World Heritage Site is roughly the size of Manhattan, and is one of the world's most important seabird colonies. Some 10 million birds from over 20 different species – including albatrosses, penguins and petrels – call the island home. Unfortunately for them, house mice were introduced to the island in the 19th century. With no predators to fall victim to, the mouse population – as well as the size of the mice themselves – has grown out of hand.

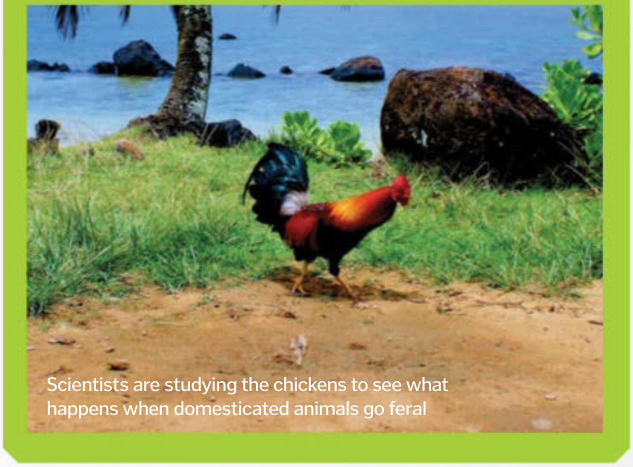
There are now almost 2 million mice on the island, and they grow 50 per cent bigger than the average house mouse. These supersized rodents are currently causing chaos among the bird populations. Studies have shown that the already endangered Atlantic petrel is particularly vulnerable. It is estimated that each year, nearly 80 per cent of petrel chicks are devoured by these mega-mice.

Free-range chickens

Kauai, Hawaii

The Hawaiian island of Kauai is overrun by wild hens and roosters. The feral flocks are found living in a diverse range of habitats across the island, from car parks to beaches.

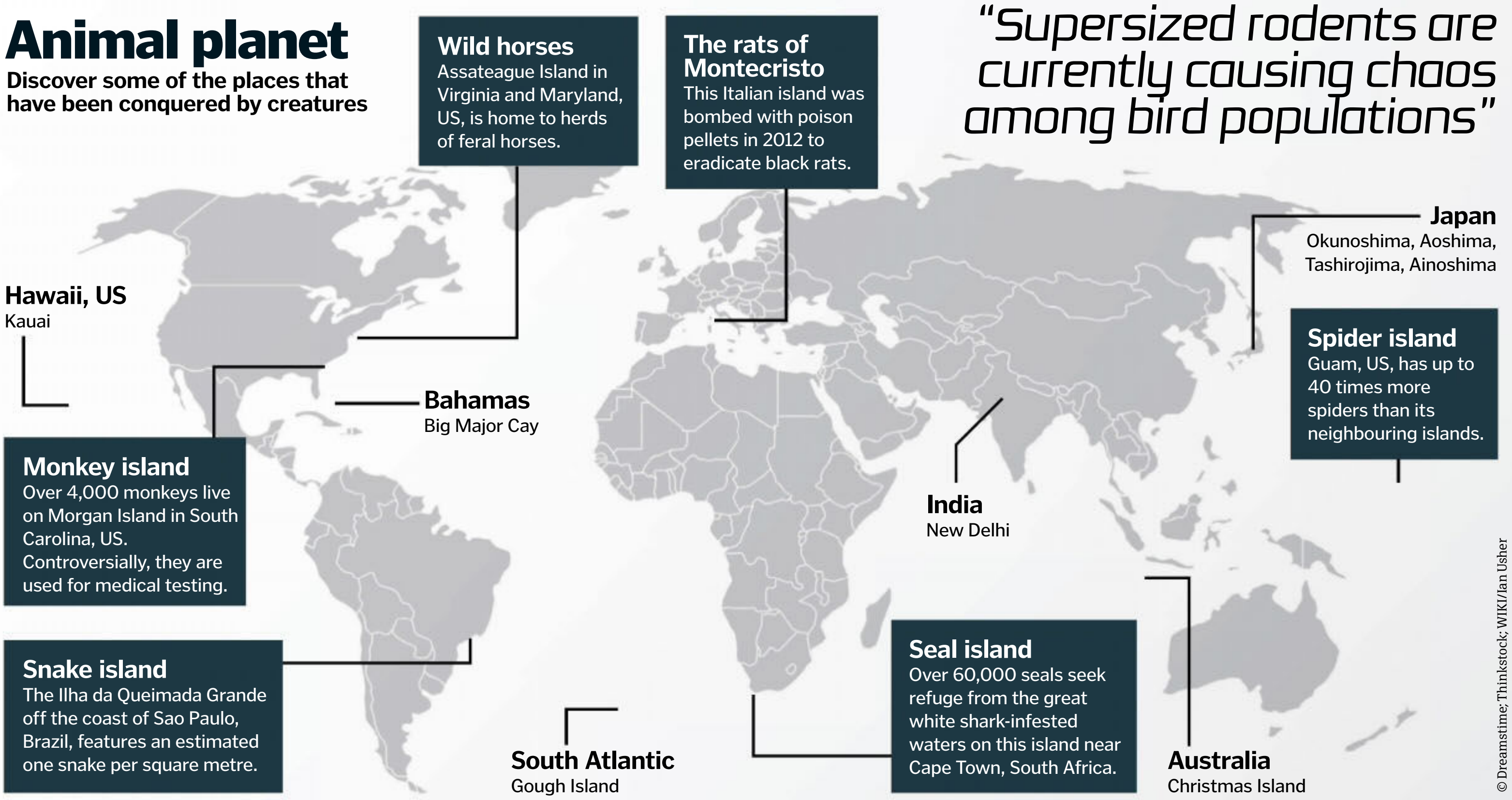
It is thought that these chickens are descended from those that escaped after hurricanes destroyed their coops. Although wild chickens are found throughout Hawaii, they are not found in such high numbers on any of the other islands. This is likely due to the fact that mongooses – which would eat the chickens and their eggs – were never released on Kauai.


Scientists are studying the chickens to see what happens when domesticated animals go feral

Animal planet

Discover some of the places that have been conquered by creatures

> *"Supersized rodents are currently causing chaos among bird populations"*


Wild horses
Assateague Island in Virginia and Maryland, US, is home to herds of feral horses.

The rats of Montecristo
This Italian island was bombed with poison pellets in 2012 to eradicate black rats.

Japan
Okunoshima, Aoshima, Tashirojima, Ainoshima

Hawaii, US
Kauai

Spider island
Guam, US, has up to 40 times more spiders than its neighbouring islands.

Bahamas
Big Major Cay

Monkey island
Over 4,000 monkeys live on Morgan Island in South Carolina, US. Controversially, they are used for medical testing.

India
New Delhi

Snake island
The Ilha da Queimada Grande off the coast of Sao Paulo, Brazil, features an estimated one snake per square metre.

Seal island
Over 60,000 seals seek refuge from the great white shark-infested waters on this island near Cape Town, South Africa.

South Atlantic
Gough Island

Australia
Christmas Island

© Dreamstime; Thinkstock; WIKI/Ian Usher

Why are rain clouds grey?

The reason why overcast days are so dismal

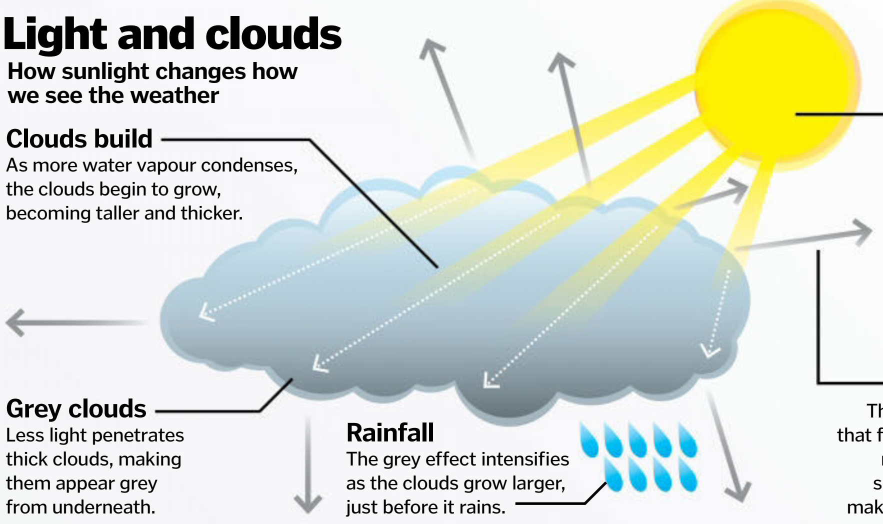
To understand why clouds can appear grey, you first need to know why they also appear white. It's all to do with the reflection of light. Clouds are formed when air and water vapour near the ground warms up and rises. As it gets higher, the water vapour condenses, and the droplets join together to form clouds. The more condensation there is, the more droplets there are and the bigger the clouds become.

When light from the Sun passes through these large accumulations of water vapour, the droplets scatter the light in all directions. The droplets are small and spread out enough to scatter the entire spectrum of light, which means that they appear white.

As more water droplets gather and the clouds grow larger, less light is able to penetrate through the cloud. What we see from the ground appears grey because less light is being scattered to our eyes. As the water droplets within the cloud get larger, this effect is enhanced, which is why clouds appear much darker just before it rains.

Light and clouds

How sunlight changes how we see the weather



Clouds build
As more water vapour condenses, the clouds begin to grow, becoming taller and thicker.

Sunlight
Light from the Sun shines into the cloud, which is formed as water vapour cools and condenses.

Grey clouds
Less light penetrates thick clouds, making them appear grey from underneath.

Rainfall
The grey effect intensifies as the clouds grow larger, just before it rains.

Reflection
The small droplets that first form a cloud reflect the entire spectrum of light, making it look white.

Know your avocado

Five facts you didn't know about this popular fruit

1 They're actually berries

Although their colour makes them look like vegetables, avocados are actually a fruit. They're botanically classed as a single-seeded berry of the Persea americana tree, native to Mexico and Central America.

2 There are hundreds of types

One worldwide favourite is the Hass variety. This delicious avocado was discovered by accident, as Californian postman Rudolph Hass grew the first tree from an unknown seedling in 1926.

3 They contain more potassium than bananas

Avocados are packed with nutrients, with nearly 20 vitamins, minerals and micronutrients in every little green fruit. They're also a source of protein and unsaturated fat, which can help to lower people's cholesterol.

4 Inca tribes ate them

Archaeological evidence suggests that wild avocados have been eaten for almost 10,000 years in Mexico! It's thought that humans started cultivating avocados around 5,000 years ago, and they were eaten by Inca, Olmec and Mayan tribes.

5 The stone can grow into a tree

You can grow your own avocado tree using the pit of the fruit you just ate. Seeds only take two to six weeks to germinate, but the trees will take at least five years to bear fruit.

©Thinkstock; Dreamstime

Figs and their wasps

Explore this curious, co-dependent relationship, and see why each species can't exist without the other

Figs are full of fibre, a great source of vitamins, and packed with nutrients such as copper, manganese and potassium. They also contain digested wasp bodies, thanks to an incredible, mutually dependent relationship between figs and fig wasps, which has evolved over millions of years and is vital to the survival of both.

Each species of wasp targets a specific species of fig, and the relationship is based upon the fact that female wasps need a safe place to lay eggs, and fig trees must be pollinated to reproduce.

A female fig wasp will enter the fruit and lay her eggs inside, depositing pollen from another fig. The fig is now fertilised and starts to mature. However, the process of entering the fruit tears the female's wings off, so she is unable to leave again, and dies inside the fig soon after.

Wasp eggs develop as the fig matures, and the males hatch first. While still inside the fig, they fertilise the females, dig escape tunnels for the ladies and then die. The female hatchlings exit through the tunnels, carrying the fig's pollen. They then take to the skies and find another fig plant to enter and lay eggs in. It's like the pollen is the currency, the fig is the private maternity ward, and the wasp is the paying guest.

You may be worrying that all this wasp death means you are munching on dead insect bodies as you eat a fig, but actually the remains are quickly broken down by enzymes within the fruit. The crunchy bits are just seeds!

Inverted flowers

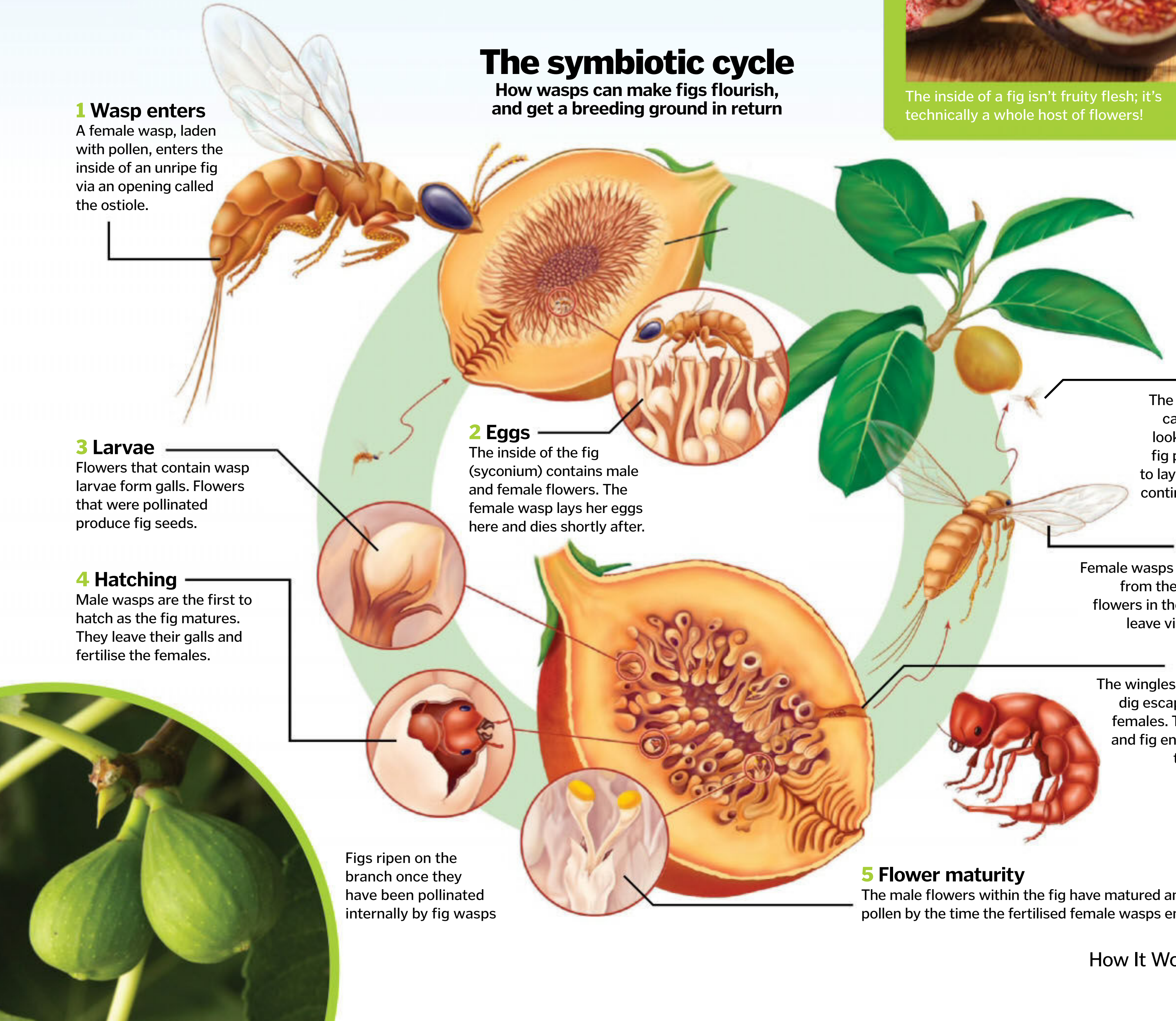
This whole process is only able to happen because of the fig's biology. Although very commonly described as a single fruit, a fig is technically not a fruit at all. It's actually a 'multiple fruit' where the flowers are inverted. Male and female flowers develop individually on the inside of the fig. Slice one open and you will see many different strands around the outside that grow towards the centre – these are the flowers!

The female flowers receive the pollen that is brought into the syconium (the inside of the fig) by the fig wasp, and then produce seeds for the plant, enabling it to reproduce. The male flowers within the syconium produce pollen, which is then picked up by the female wasp hatchlings as they leave.

The inside of a fig isn't fruity flesh; it's technically a whole host of flowers!

The symbiotic cycle

How wasps can make figs flourish, and get a breeding ground in return



1 Wasp enters
A female wasp, laden with pollen, enters the inside of an unripe fig via an opening called the ostiole.

2 Eggs
The inside of the fig (syconium) contains male and female flowers. The female wasp lays her eggs here and dies shortly after.

3 Larvae
Flowers that contain wasp larvae form galls. Flowers that were pollinated produce fig seeds.

4 Hatching
Male wasps are the first to hatch as the fig matures. They leave their galls and fertilise the females.

5 Flower maturity
The male flowers within the fig have matured and produced pollen by the time the fertilised female wasps emerge.

6 Tunnels
The wingless male wasps dig escape tunnels for females. They then die, and fig enzymes digest their remains.

7 Escape
Female wasps collect pollen from the mature male flowers in the ripe fig, and leave via the tunnels.

8 Repeat
The female wasp, carrying pollen, looks for another fig plant in which to lay her eggs and continue the cycle.

Figs ripen on the branch once they have been pollinated internally by fig wasps

© Getty; Dreamstime

Bird eggs: inside and out

Unscramble the fascinating fertilisation process of bird eggs

Whether you boil them, scramble them or whip them into a prize-winning soufflé, eggs are one of the most versatile ingredients in the kitchen. But have you ever wondered about the ones that don't make it onto the plate? These little capsules happen to be some of the most wondrous things in the natural world!

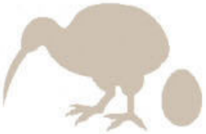
Laid by birds and reptiles, and sporting all shapes and sizes, each egg has a similar makeup – a brittle shell protects a gloopy inner of the familiar 'yolk' and 'white'. The yolk is released as the chicken ovulates; it can then be fertilised, and continues to travel through the hen's reproductive tract. The white of the egg is comprised of various different layers of albumin, structural fibres and membrane, which surround the yolk as it travels through. Finally, the eggs are 'shelled' and laid by the hen usually 24 hours later.

The fertilised yolk contains all of the genetic information needed to create a newborn chick. To support the chick's development, eggs are high in fat and protein – the more fat in the yolk, the darker the colour. Read on to find out about the development from fertilised egg to chick.

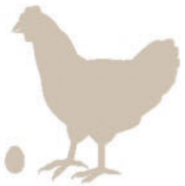
> *"The fertilised yolk contains all of the genetic information needed"*

The egg

Get to grips with egg development, from ovulating avian to hatching hen



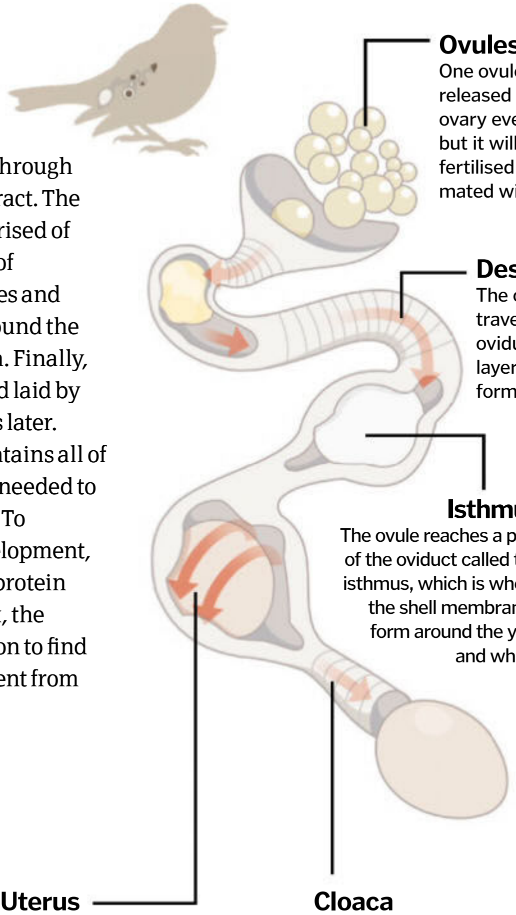
Kiwi egg



Chicken egg

Size doesn't matter

The largest egg in the world is laid by one of the biggest birds: the ostrich. But small birds can lay large eggs too. The kiwi's egg is around 20 per cent of its body weight, compared to two per cent in both an ostrich and a chicken.



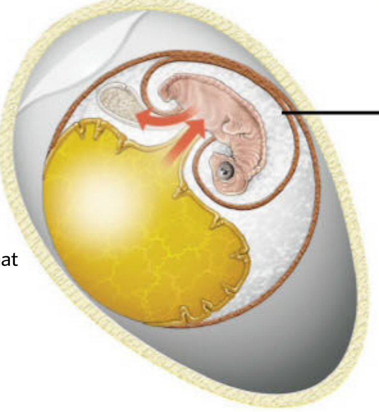
Ovules
One ovule (egg yolk) is released from the hen's ovary every 26 hours, but it will only be fertilised if the hen has mated with a rooster.

Descent
The ovule then travels down the oviduct and gains layers of albumin that form the egg white.

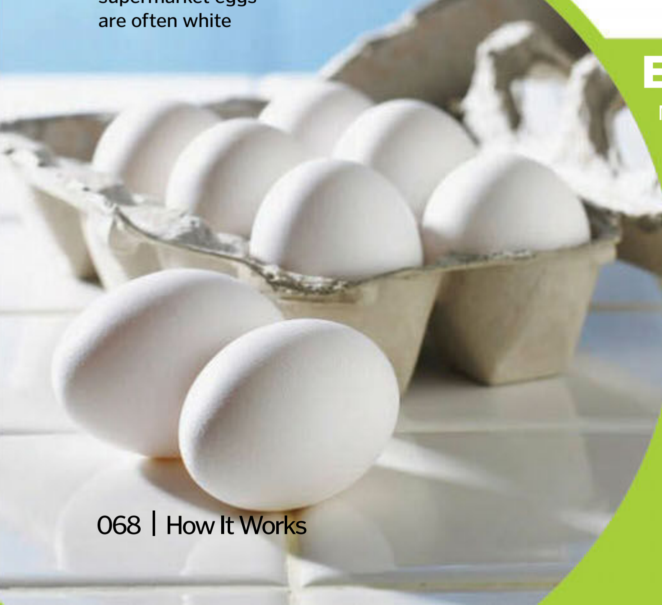
Isthmus
The ovule reaches a part of the oviduct called the isthmus, which is where the shell membranes form around the yolk and white.

Uterus
The developing egg spends around 20 hours in the uterus. Here, the calcium carbonate shell hardens and any colour pigments are deposited.

Cloaca
The egg is laid. The whole process takes around 26 hours, and a chicken can ovulate again after 60 minutes.



1 Fertilised egg
The embryo begins to develop at one side of the yolk – this is held in place in the centre of the egg white by a protein cord called the chalaza.



American supermarket eggs are often white

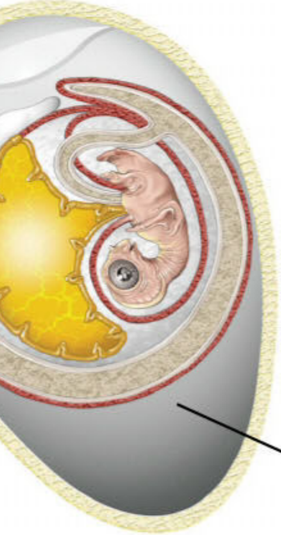
Egg aesthetics

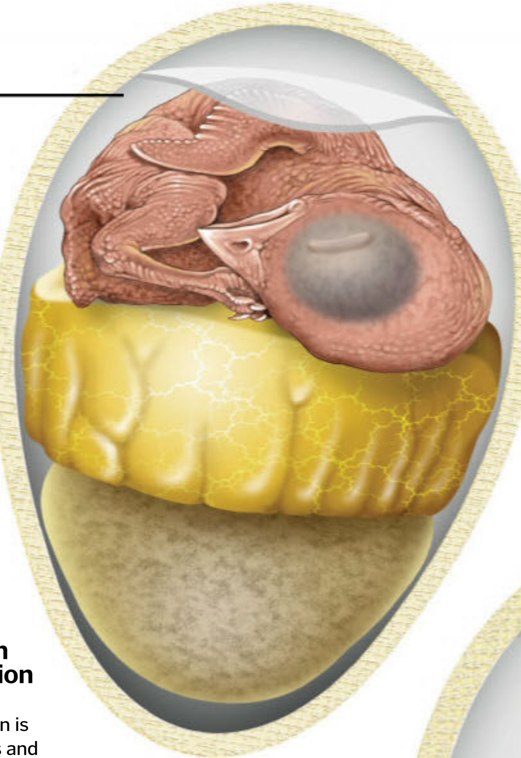
Most chicken eggs we eat in the UK are a light-brown colour, but in the US, white eggs are the norm. The colouring depends on the breed of hen, and there is little difference between the eggs otherwise. Eggs actually come in all different colours; the Araucana breed of hen lays muted blue eggs – this is due to a pigment called oocyanin, which dyes the shell.

There are also breeds that lay cream, pink or olive-green eggs. Crossbreeding results in hens known as 'Easter eggers', which produce large eggs in all sorts of colours.

Many other bird species lay speckled eggs, though the reason for this is debated among experts. Many believe that the speckles act as camouflage to keep developing eggs safe from hungry predators, but this hasn't been observed in the wild – in fact, the speckles may even make them stand out! Recent research suggests the speckles actually show where extra pigment has been added to support a weak area of shell.

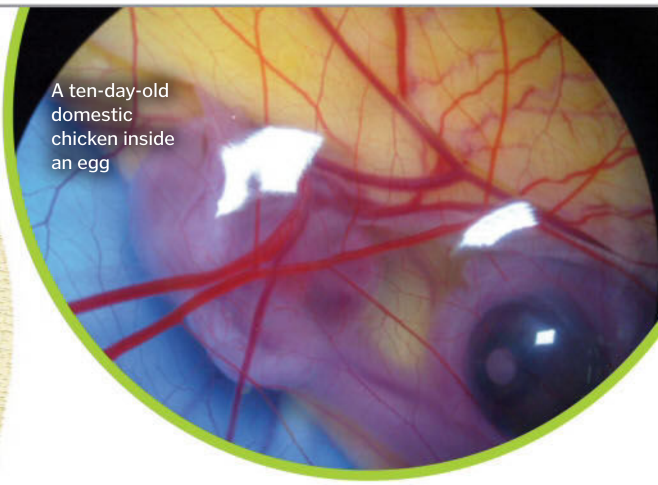
DID YOU KNOW? The egg came first! Chickens are descended from dinosaurs, who were laying eggs before chickens evolved



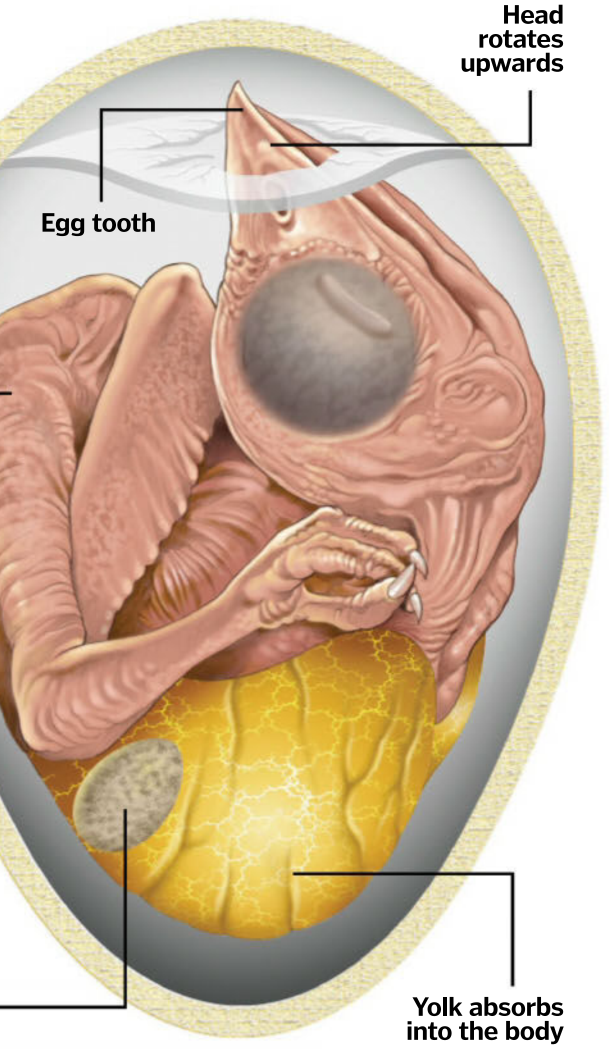


4 14 to 17 days’ incubation

The embryo now fully resembles a chick, down has covered its body, and days 15 and 16 are spent growing. By day 17, the egg white is used up, and the chick starts to get into hatching position.



A ten-day-old domestic chicken inside an egg



2 Three days’ incubation

Blood vessels are present, and the embryo has a heartbeat. After five days, there is substantial growth and the tiny chick has an eye. The embryo feeds on nutrients from the yolk through the blood vessels.

3 Nine to eleven days’ incubation

The embryo’s neck has lengthened and its brain is developing. Claws, legs and wings begin to show and lengthen, and there are also feather follicles forming as more blood vessels draw sustenance from the yolk.

Shape

Eggs are advantageously oval-shaped. They are easier for birds to lay, fit snugly into a nest, and they roll in a circle.

Spherical eggs (which are laid by owls and woodpeckers) are better at conserving heat.

Seabirds nesting on cliffs often lay conical eggs – they roll in a tight circle to better avoid edges.

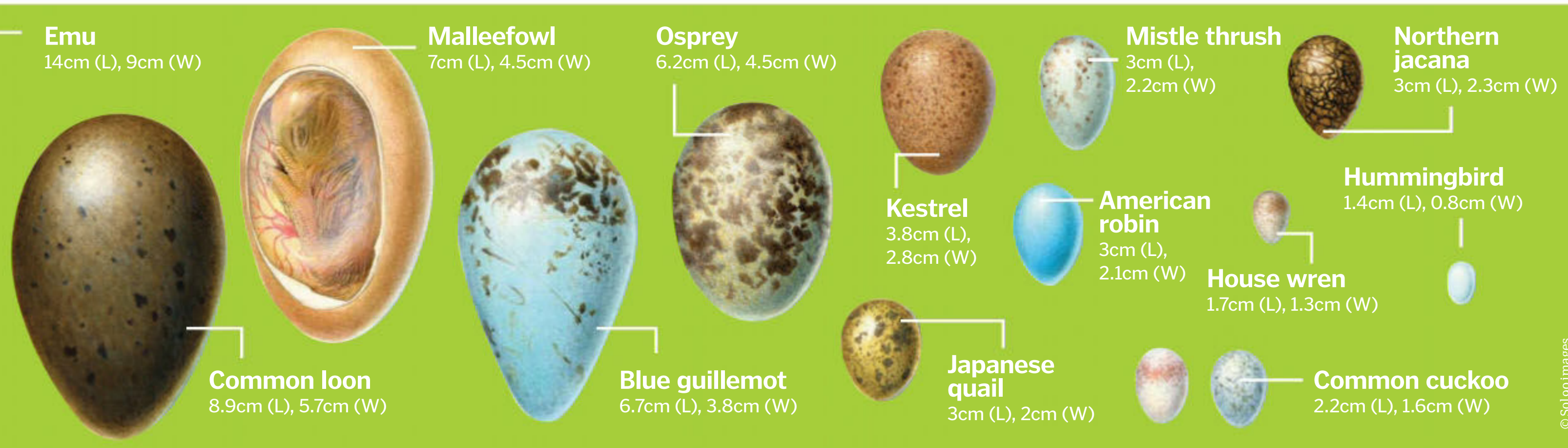
Oval is the most common shape.

Colour and texture

Disguising eggs from hunters is key to survival. Texture and colour can tailor an egg to a bird’s surroundings.

5 Hatching

After 20 days, the white and yolk have been absorbed and the chick is fully formed. It has rotated within the egg so that it can break the shell using its egg tooth – the hardened end of its tiny beak.



© Sol90 images

The StarChip will be accelerated by lasers to 20 per cent the speed of light

INTERSTELLAR SPACE TRAVEL

The multimillion-dollar project taking us further into space than ever before

To date, we've done a pretty good job of exploring the Solar System. But in our half a century or so as a space-faring species, we have not yet truly ventured to any of the 100 billion stars in our own galaxy, or beyond. In 20 years, though, that could all be set to change.

On 12 April 2016, Russian billionaire Yuri Milner announced an ambitious project as part of the Breakthrough Initiatives to send a series of small spacecraft to the nearest stars to our own Sun, the Alpha Centauri system. And he wasn't alone; alongside him at this announcement were respected scientists, including Stephen Hawking and Kip Thorne, who have all signed up to help with the project. "The human story is one of great leaps," said Milner. "55 years ago, Yuri Gagarin became the first human in space. Today, we are preparing for the next great leap – to the stars."

So, what's it all about? The project is known as Breakthrough Starshot, and it is utilising an oft-touted – but little explored – technique known as laser sails to reach tremendous speeds, and make a trip to another star possible in as little as a generation.

You've probably heard of solar sails before. These are sheets of thin material that expand to massive sizes in space. Like a wind sail on Earth, these sails then pick up speed not from regular wind, but solar wind, the stream of particles given off by our Sun. The rate of acceleration is very slow but over time, a spacecraft could theoretically reach a significant fraction of the speed of light.

This proposal is slightly different, though. Instead of using solar wind, the team is proposing to fire giant lasers on Earth at sail-mounted spacecraft. These spacecraft, known as a StarChips, would have several instruments packed into them, but be small enough to fit on the palm of your hand, thanks to huge advances in techology. The sail itself would be larger, spanning a metre, although just a few hundred atoms thick. Theoretically, shining a 100-gigawatt laser on one of the sails should accelerate the spacecraft to 20 per cent of the speed of light – or 216 million kilometres per hour – in minutes.

At these speeds, traversing the Solar System would be a breeze. In hours, the spacecraft would reach Mars, a journey that takes several months for conventional spacecraft powered by chemical fuels. In three days, it would reach Pluto, which took New Horizons almost ten years to reach. Most importantly, in 20 years, the spacecraft would reach Alpha Centauri, 4.37 light years (40 trillion kilometres) away.

Alpha Centauri's three stars are the closest to our Sun

One of the main reasons for going to Alpha Centauri – which is actually a triple system made of three stars – is that it's the closest star system to our Sun. We now think that almost every star plays host to at least one planet, and Alpha Centauri A, B and C should be no exception. The goal of the mission would be to study these planets, returning images and priceless data to Earth. Owing to the distance, this information – travelling at the speed of light – would take 4.37 years to make it back. But a total of less than 25 years for such data is pittance, considering the implications.

"Earth is a wonderful place, but it might not last forever," Stephen Hawking said in a statement from Breakthrough Starshot. "Sooner or later, we must look to the stars. Breakthrough Starshot is a very exciting first step on that journey." So far, so good. But this is just scratching the surface of the technical challenge of this hugely ambitious project. We've never sent a spacecraft beyond 240,000 kilometres per hour before; the StarChip would travel almost 1,000 times faster. There will be a huge number of unknowns of accelerating to and travelling at these speeds. How the spacecraft will hold itself together during the intense acceleration phase, and how it will communicate with Earth at great distances, will also need to be resolved.

Breakthrough Starshot, therefore, is a bid to overcome such hurdles. Milner is investing $100 million of his own money, but he readily admits that this is merely seed funding. The final cost of the mission could spiral into the billions of dollars, and he is hoping for funding from a number of sources in order to support the project. As such, there is no definitive launch date yet, although some time in the next couple of decades is not unthinkable.

One way to overcome some of the challenges facing the project will be to send not just one spacecraft, but to launch a 'mothership' with thousands of StarChips on board. All of them

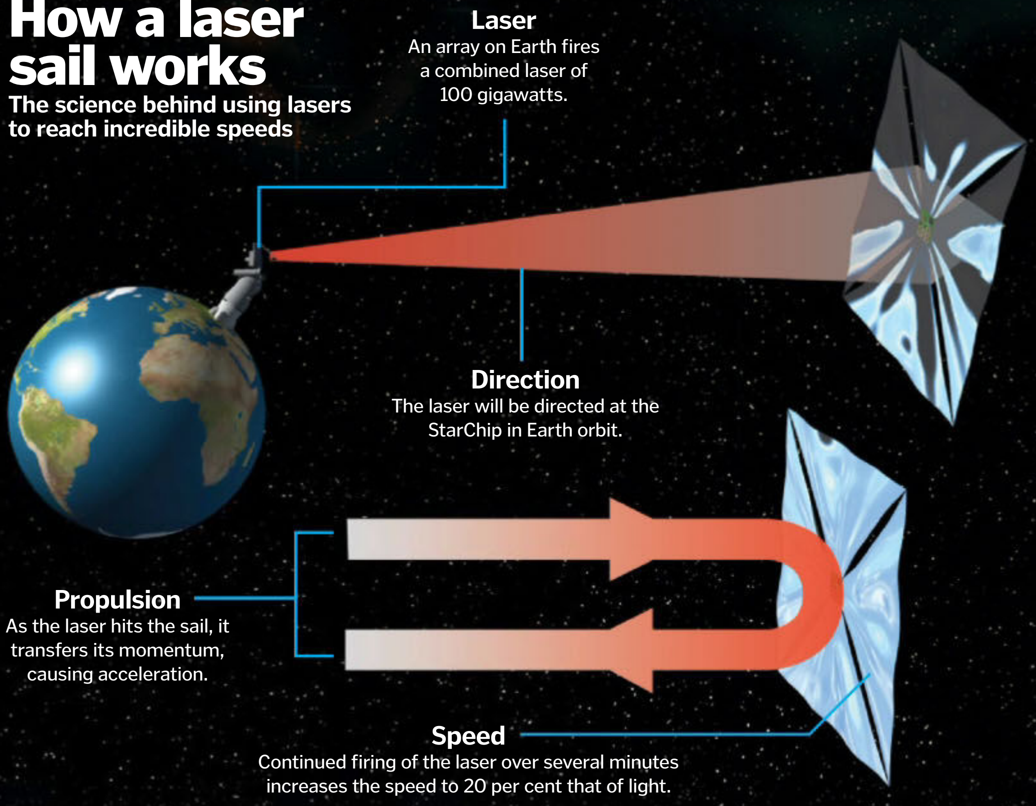
Sailing to the stars

To travel at high speeds, Breakthrough Starshot's nanocrafts will be propelled by a powerful laser on Earth. Each would be a chip weighing just one gram, with communications, cameras and a battery built in. But expanding from this would be a larger sail spanning a metre. An array of lasers on Earth would shine a combined 100 gigawatts on the spacecraft. Each one would accelerate 60,000 times faster than Earth's gravity, reaching 20 per cent of the speed of light in just two minutes. At these speeds the journey to Alpha Centauri, just over four light years away, would take 20 years.

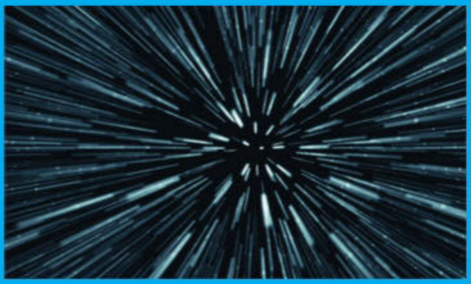
Yuri Milner (third from left) and other scientists, such as Stephen Hawking (front centre), announcing Breakthrough Starshot

How a laser sail works

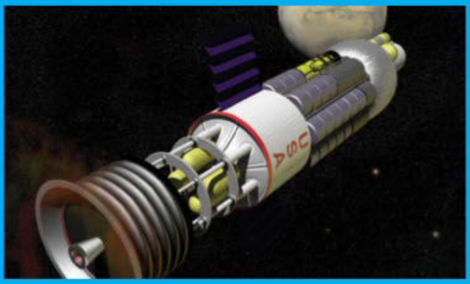
The science behind using lasers to reach incredible speeds


Laser
An array on Earth fires a combined laser of 100 gigawatts.
Direction
The laser will be directed at the StarChip in Earth orbit.
Propulsion
As the laser hits the sail, it transfers its momentum, causing acceleration.
Speed
Continued firing of the laser over several minutes increases the speed to 20 per cent that of light.

Exploring space



Warp travel
Some theories suggest it may be possible to 'warp' space time, allowing us to travel huge distances in a short amount of time. This is mostly science fiction at the moment, though.



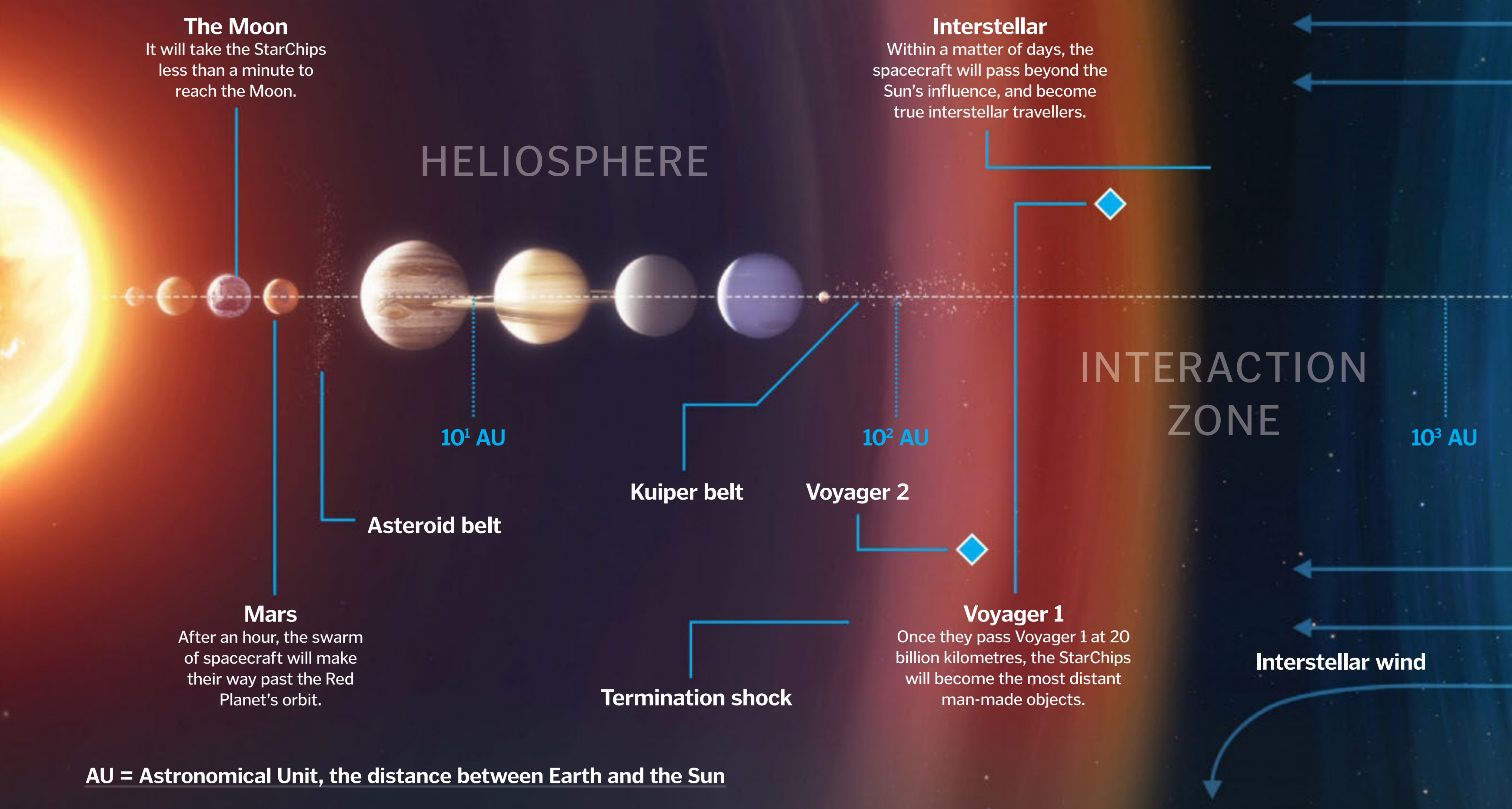
Nuclear power
Launching a spacecraft with nuclear reactors would give it a lengthy source of fuel, allowing it to accelerate and decelerate constantly to reach far-off destinations, but safety is a concern.

Slow and steady
Instead of fast travel, we could send a colony of humans on a 'generation ship', with them travelling for hundreds of years towards a new world.

© Breakthrough Initiatives; Alamy; Thinkstock; SPL

Breakthrough Starshot timeline

Here's how the spacecraft will make their way beyond the Solar System



The Moon
It will take the StarChips less than a minute to reach the Moon.

Interstellar
Within a matter of days, the spacecraft will pass beyond the Sun's influence, and become true interstellar travellers.

Mars
After an hour, the swarm of spacecraft will make their way past the Red Planet's orbit.

Voyager 1
Once they pass Voyager 1 at 20 billion kilometres, the StarChips will become the most distant man-made objects.

AU = Astronomical Unit, the distance between Earth and the Sun

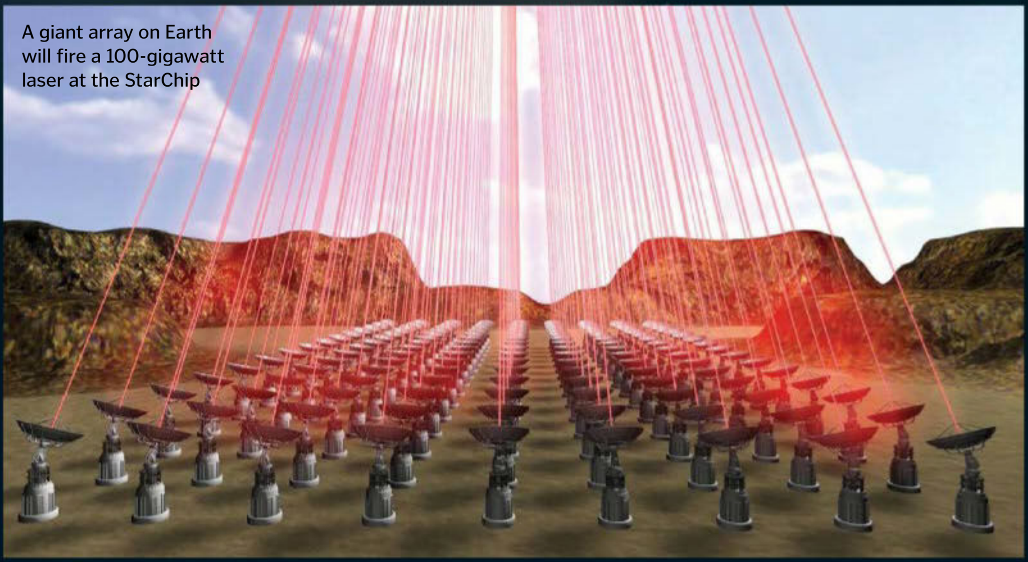
would be released in orbit, where the powerful Earth-based laser would shine upon them, firing them off in the direction of Alpha Centauri. Think of this mission not as a single man-made vehicle making a lonely journey, but an entire fleet venturing off into the cosmos.

If it works, this form of propulsion could prove invaluable. Not only would it let us reach Alpha Centauri in 20 years, but it would also let us explore destinations closer to home, such as the Moon and Mars, in a tiny fraction of the time that is currently possible. Imagine if, on a regular basis, scientific organisations from around the world could send their own prospecting spacecraft to places all over the Solar System, letting us frequently explore worlds closer to home, rather than sending a mission every few years or so.

Once the spacecraft reached Alpha Centauri, they would not stay for long. Owing to the method of travel, this would very much be a one-way trip. The spacecraft would merely fly by any worlds we discover, snapping as many images as possible and gathering data. They may also collect information on the atmospheric composition of the planets, their temperature, their rotation rate, and so on.

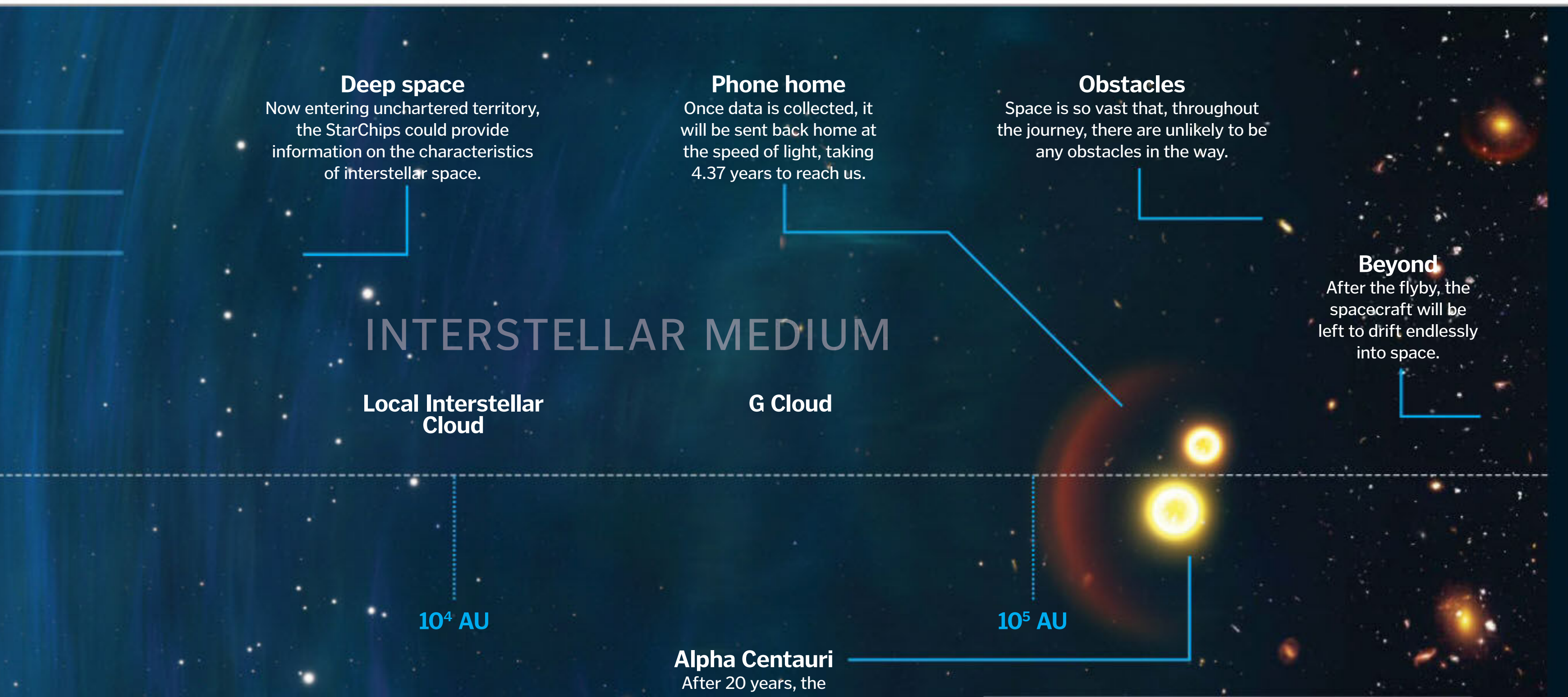
As for Alpha Centauri itself, the system may hold invaluable secrets. At the moment, we're not actually sure if any of the three stars host planets. Previous detections have since been ruled uncertain. But it's fair to assume there are probably some planets in orbit, considering two of the stars are similar to our Sun. We know all stars form in a debris of dust and gas, a planetary disc, which often gives rise to planets. It's hoped the same would be true of Alpha Centauri.

Initially, astronomers had thought that there was a planet orbiting in the desirable habitable zone of one of the stars, Alpha Centauri B, an orbital position that is not too hot nor too cold, where liquid water is able to form on the surface. The nature of whatever planets are there still remains uncertain, but



A giant array on Earth will fire a 100-gigawatt laser at the StarChip

DID YOU KNOW? *The first planet outside the Solar System was not discovered until 1992, but thousands have been found since*



Deep space
Now entering unchartered territory, the StarChips could provide information on the characteristics of interstellar space.

Phone home
Once data is collected, it will be sent back home at the speed of light, taking 4.37 years to reach us.

Obstacles
Space is so vast that, throughout the journey, there are unlikely to be any obstacles in the way.

Beyond
After the flyby, the spacecraft will be left to drift endlessly into space.

Alpha Centauri
After 20 years, the spacecraft will reach the Alpha Centauri system and begin their mission.

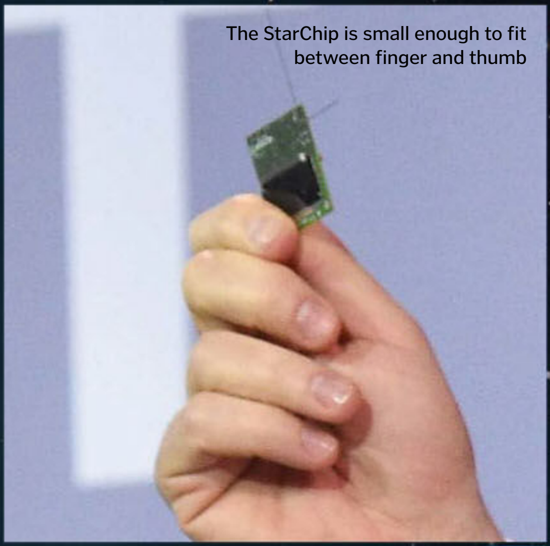
Oort Cloud
It will take more than five years to exit the Oort Cloud, the region of comets surrounding our Solar System.

the chances that one might be habitable are indeed fascinating.

For decades now, we have been looking for worlds beyond our own that are Earth-like; that is, they have the necessary conditions to host life. After all, we are just one planet orbiting one of 100 billion stars in one of 100 billion galaxies. It seems unlikely that ours is the only planet teeming with life. But so far, finding planets exactly like our own has been difficult, owing to the limited methods of detection we currently employ. However, if we could send probes to a potentially habitable world around Alpha Centauri, we may be able to discover if our planet really is unique – or if there are many others like it. Imagine images being returned of a glorious alien world abundant in water, clouds or perhaps even vegetation. Such a discovery would no doubt change life on Earth forever, with untold money being pumped into missions to find more worlds like our own – and even visit them.

For now, the project is in its infancy, and these dreams are at least 40 years away. But perhaps we'll soon make the first steps to becoming a truly interstellar species, and discover our place among the stars.

> "Sooner or later, we must look to the stars"
> *Stephen Hawking*



The StarChip is small enough to fit between finger and thumb

© Breakthrough Initiatives; SPL

The Alpha Centauri System

Alpha Centauri is not a single star. The system is actually composed of three stars: Alpha Centauri A and B, which are somewhat similar to the Sun, and Alpha Centauri C, or Proxima Centauri, which is a small and faint red dwarf. It's not known which of the three Breakthrough Starshot would visit yet.

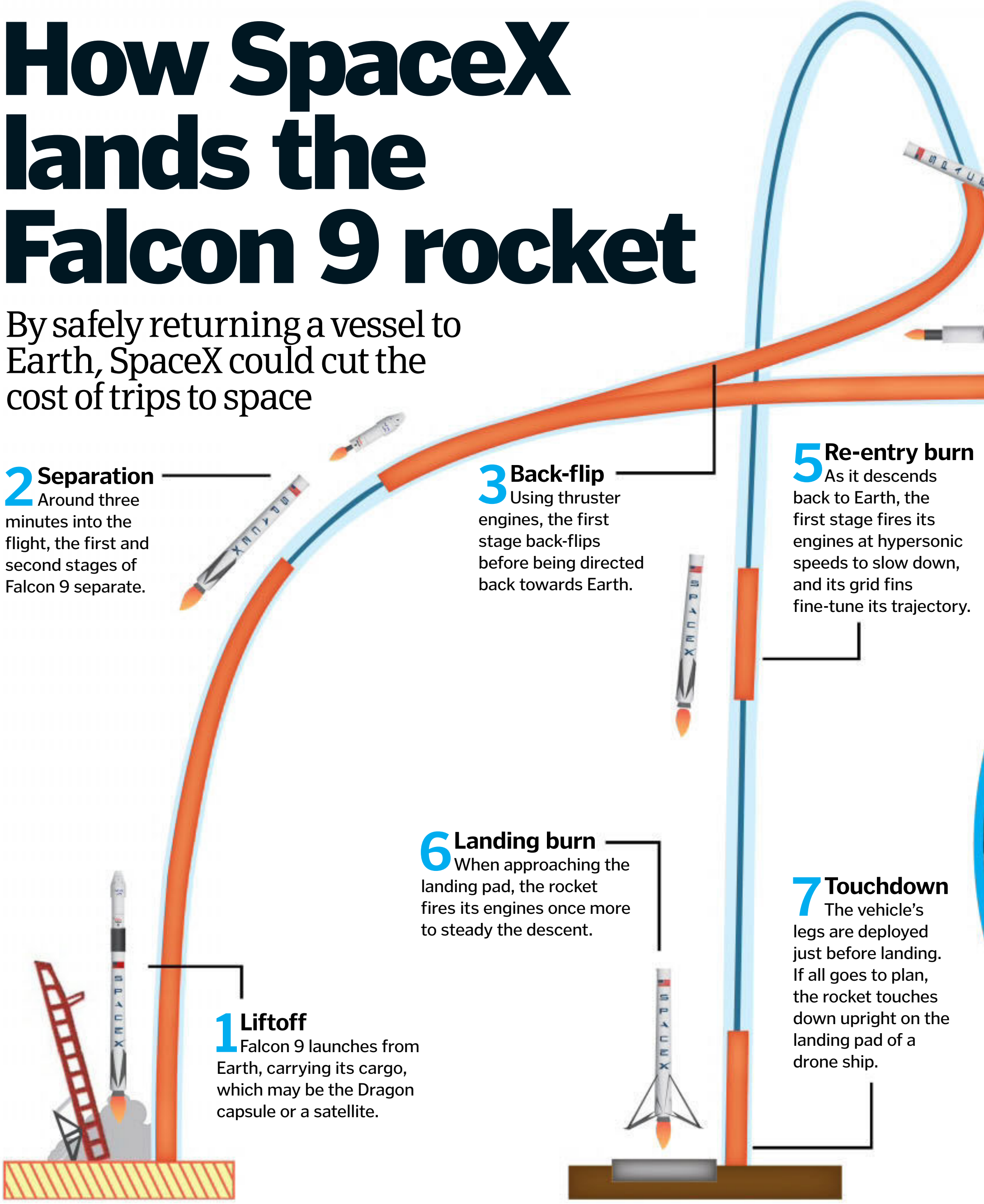
Early in 2015, it was announced that Alpha Centauri B might play host to a planet, dubbed Alpha Centauri Bb, which was thought to be located in a tight and uninhabitable orbit. Later research suggested that Alpha Centauri Bb might not actually exist at all, and could simply have been a blip in observations. But considering how similar two of these stars are to our Sun, it is rather likely that at least one has some planets – and with more powerful telescopes in the future, these should hopefully reveal themselves.

By sending spacecraft there, we could return not only images of these planets, but also information on their atmospheres, and potential habitability. Even if they're molten rocks, images of such alien worlds would be astounding.

It's quite likely there are planets in the triple Alpha Centauri system

How SpaceX lands the Falcon 9 rocket

By safely returning a vessel to Earth, SpaceX could cut the cost of trips to space



1 Liftoff Falcon 9 launches from Earth, carrying its cargo, which may be the Dragon capsule or a satellite.

2 Separation Around three minutes into the flight, the first and second stages of Falcon 9 separate.

3 Back-flip Using thruster engines, the first stage back-flips before being directed back towards Earth.

4 Into orbit The second stage continues ascending to carry the Dragon or satellite to orbit.

5 Re-entry burn As it descends back to Earth, the first stage fires its engines at hypersonic speeds to slow down, and its grid fins fine-tune its trajectory.

6 Landing burn When approaching the landing pad, the rocket fires its engines once more to steady the descent.

7 Touchdown The vehicle's legs are deployed just before landing. If all goes to plan, the rocket touches down upright on the landing pad of a drone ship.

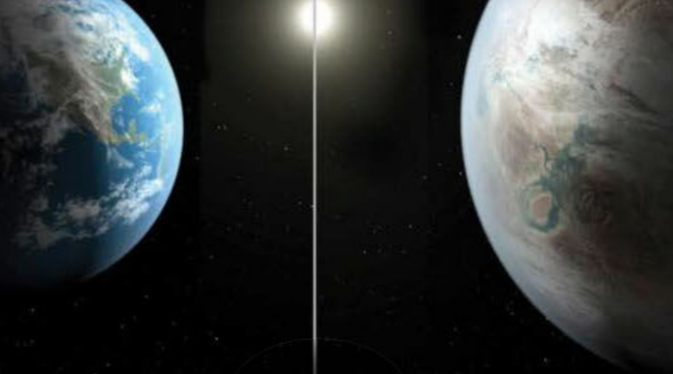
Falcon 9 was designed to safely transport satellites into orbit

Searching for super-Earths

There are rocky planets bigger and more massive than Earth orbiting stars many light years away, but why do we seek them out?

Over the last decade or so, astronomers have discovered that there are rocky planets up to ten times more massive than Earth orbiting other stars. They call them 'super-Earths', although that can be misleading as they may look nothing like our planet at all. They are, however, the easiest rocky exoplanets that scientists can detect. Their hefty mass means their gravity causes stars to wobble to a greater extent, giving away their presence, while their large diameter causes a dip in brightness when they are seen transiting across the face of their star.

Could they support life? It's possible – some super-Earths have been found in the habitable zones of stars, where the temperature would allow liquid water to exist. The conditions wouldn't be the same as on Earth, however, as surface gravity would be stronger, the geological activity may be different and the atmospheres are often found to be thick, which makes it easier to study the gases present. Above all, astronomers are invested in the search for super-Earths because we have none in our Solar System. That means they are among the most alien of planets we have discovered so far.



An artist's impression of a super-Earth (right) in the habitable zone of a star, compared to Earth (left)

Journey to Jupiter

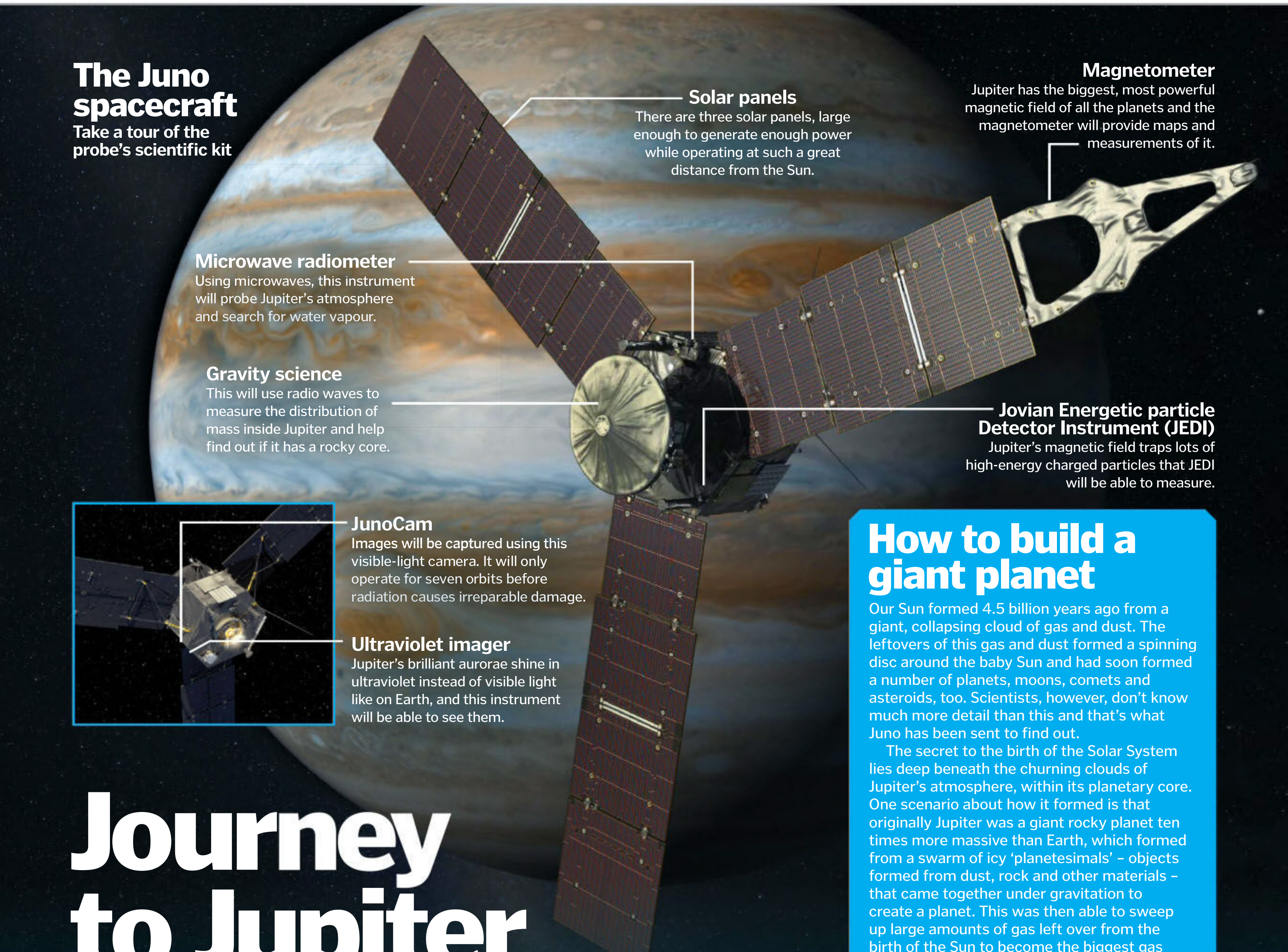
The secrets of the king of the Solar System are about to come under the scrutiny of a bold new mission

NASA's Juno spacecraft has been racing towards Jupiter at 97,000 kilometres per hour since leaving Earth in 2011. When it arrives on 4 July 2016 it will have travelled 2.8 billion kilometres, setting the record for the most distance a solar-powered probe has ever flown.

Jupiter is the largest planet in the Solar System, spanning 143,000 kilometres across and weighing in at 318 times more than Earth. It's a gas giant, which means it's mostly made of hydrogen and helium gas, and its appearance is famous for the stripes of creamy white, orange and brown. The biggest cloud pattern is the Great Red Spot, a huge anticyclonic storm that's big enough to fit our entire planet inside!

What lies deep within Jupiter's core is still a mystery, however. What does its gaseous composition tell us about the materials that went into its creation? Does the atmosphere contain water, and what lurks beneath the cloud tops? Juno will attempt to unravel these mysteries, while also going where no other spacecraft has gone before by flying close over the poles of Jupiter. Here, it will be able to observe the dazzling northern and southern lights and learn how they are created by the planet's magnetic field. Incidentally, that's what inspired Juno's name: JUpiter Near-polar Orbiter.

The spacecraft will have two years to unlock secrets of the giant planet before it runs out of fuel and is sent hurtling into Jupiter itself. This is to avoid crashing into Jupiter's moon Europa, where it could contaminate any alien life that may inhabit the moon's underground ocean.



The Juno spacecraft

Take a tour of the probe's scientific kit

Solar panels
There are three solar panels, large enough to generate enough power while operating at such a great distance from the Sun.

Magnetometer
Jupiter has the biggest, most powerful magnetic field of all the planets and the magnetometer will provide maps and measurements of it.

Microwave radiometer
Using microwaves, this instrument will probe Jupiter's atmosphere and search for water vapour.

Gravity science
This will use radio waves to measure the distribution of mass inside Jupiter and help find out if it has a rocky core.

Jovian Energetic particle Detector Instrument (JEDI)
Jupiter's magnetic field traps lots of high-energy charged particles that JEDI will be able to measure.

JunoCam
Images will be captured using this visible-light camera. It will only operate for seven orbits before radiation causes irreparable damage.

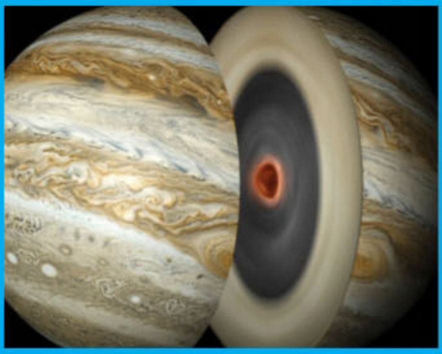
Ultraviolet imager
Jupiter's brilliant aurorae shine in ultraviolet instead of visible light like on Earth, and this instrument will be able to see them.

How to build a giant planet

Our Sun formed 4.5 billion years ago from a giant, collapsing cloud of gas and dust. The leftovers of this gas and dust formed a spinning disc around the baby Sun and had soon formed a number of planets, moons, comets and asteroids, too. Scientists, however, don't know much more detail than this and that's what Juno has been sent to find out.

The secret to the birth of the Solar System lies deep beneath the churning clouds of Jupiter's atmosphere, within its planetary core. One scenario about how it formed is that originally Jupiter was a giant rocky planet ten times more massive than Earth, which formed from a swarm of icy 'planetesimals' – objects formed from dust, rock and other materials – that came together under gravitation to create a planet. This was then able to sweep up large amounts of gas left over from the birth of the Sun to become the biggest gas giant in the Solar System.

An alternative theory is that Jupiter never had a rocky core and instead condensed out of gas like the Sun did. By carefully measuring Jupiter's magnetic and gravitational fields, Juno will be able to assess whether it has the remnants of a rocky core or not and determine which scenario is correct. If Jupiter does have a rocky core, then it means that the planetesimal theory is likely, and planetesimals can then be used to explain the formation of other planets, including our own.



If we could cut Jupiter in half, would we find a vaporised rocky core deep underneath the gas?

© NASA/JPL-Caltech

On board the SpaceShipTwo

Could this be the vehicle that will take you to space?

Virgin Galactic's reusable spaceplane, SpaceShipTwo, is designed to take two pilots and six passengers on the trip of a lifetime. Made by The Spaceship Company, part of Virgin Galactic, this vessel will be carried high into the atmosphere by the jet-powered aircraft WhiteKnightTwo, before engaging its rocket engines for a brief trip out of this world.

With 12 windows on the walls and ceiling to marvel at the view, and articulated seats for optimum journey comfort, it has been designed specifically with space tourism in mind. Passengers will be able to look up at the stars and down at the Earth below during a controlled flight in a spaceship that looks like a plane. After their adventure, they will glide back through the atmosphere, before landing on a runway.

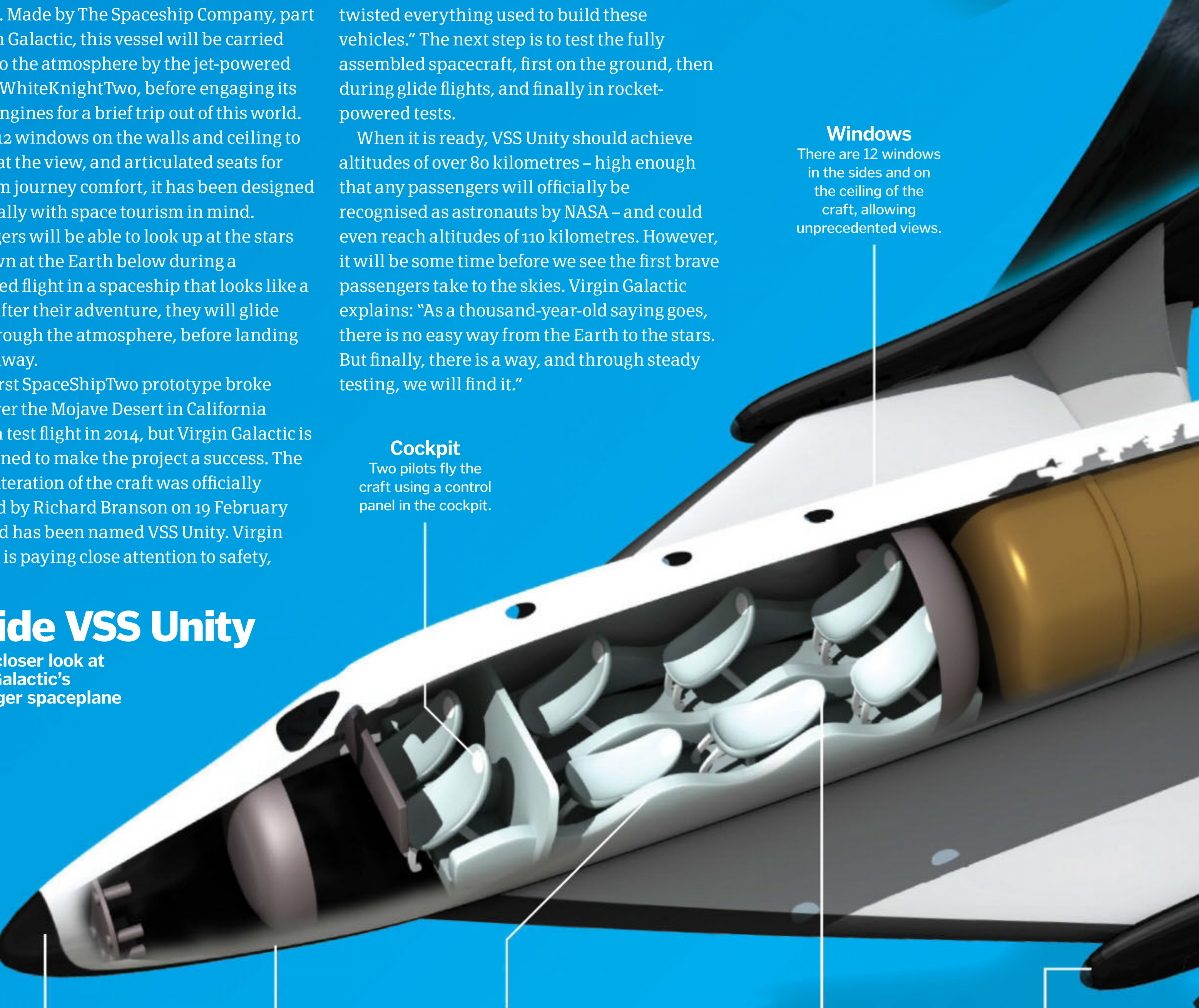
The first SpaceShipTwo prototype broke apart over the Mojave Desert in California during a test flight in 2014, but Virgin Galactic is determined to make the project a success. The second iteration of the craft was officially unveiled by Richard Branson on 19 February 2016, and has been named VSS Unity. Virgin Galactic is paying close attention to safety, commenting in a statement: "Starting at the level of individual pieces and components, we poked, prodded, stretched, squeezed, bent and twisted everything used to build these vehicles." The next step is to test the fully assembled spacecraft, first on the ground, then during glide flights, and finally in rocket-powered tests.

When it is ready, VSS Unity should achieve altitudes of over 80 kilometres – high enough that any passengers will officially be recognised as astronauts by NASA – and could even reach altitudes of 110 kilometres. However, it will be some time before we see the first brave passengers take to the skies. Virgin Galactic explains: "As a thousand-year-old saying goes, there is no easy way from the Earth to the stars. But finally, there is a way, and through steady testing, we will find it."

The first powered flight of VSS Enterprise shows the spaceplane in action

Inside VSS Unity

Take a closer look at Virgin Galactic's passenger spaceplane



Windows
There are 12 windows in the sides and on the ceiling of the craft, allowing unprecedented views.

Cockpit
Two pilots fly the craft using a control panel in the cockpit.

Thrusters
Positioned at the front of the spaceplane and on the wings, thrusters provide additional control during flight.

Fuselage
The body and nose of the plane are constructed from carbon fibre.

Passenger cabin
SpaceShipTwo has been designed with the passenger's experience in mind, aiming to minimise the discomfort of G-forces.

Articulated seats
The passenger seats are upright during ascent, and reclined during re-entry.

Thrusters

DID YOU KNOW? *There has only been one eight-person crew in space before, on board NASA's Space Shuttle Challenger*

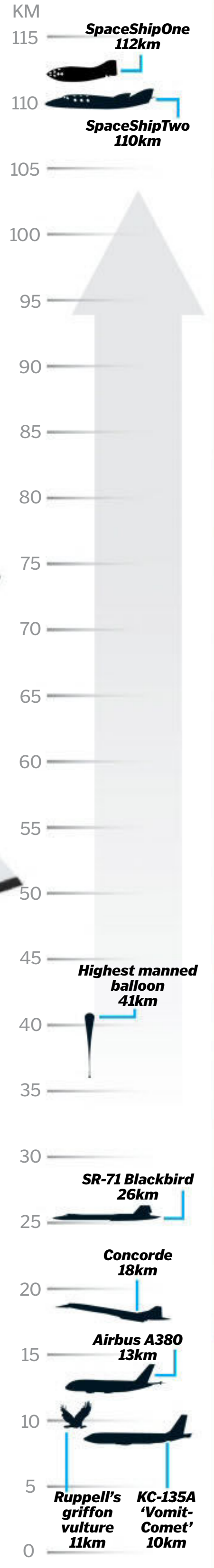
VSS Enterprise crash

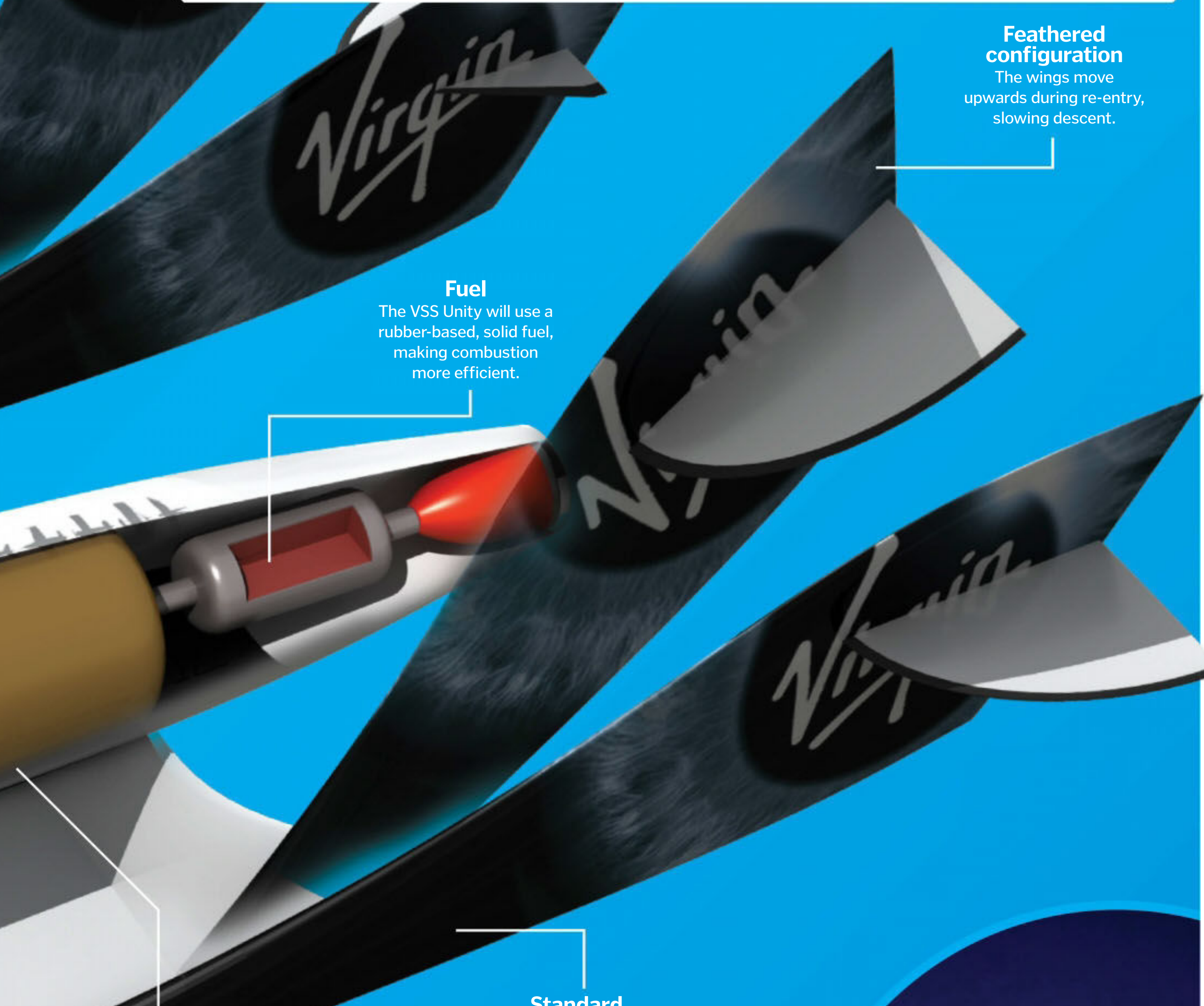
After 55 successful test flights, the first SpaceShipTwo, VSS Enterprise, broke apart over the Mojave Desert in California, killing co-pilot Michael Alsbury. SpaceShipTwo is equipped with a 'feathering system', designed to rotate the tail and wings for a smooth descent through Earth's atmosphere, but Alsbury unlocked it too early. With the rocket engine still firing, and with VSS Enterprise travelling at a little under the speed of sound, the feather system deployed, pulling the spaceplane apart. The other co-pilot, Peter Siebold, managed to parachute to safety. However, the computer system should have prevented the disaster, and it has been changed for the new SpaceShipTwo. This time, it will not be possible for the crew to unlock the feather system too soon.

The National Transportation Safety Board examines the remains of VSS Enterprise

Flying high

See how SpaceShipTwo compares to other high fliers





Feathered configuration
The wings move upwards during re-entry, slowing descent.

Fuel
The VSS Unity will use a rubber-based, solid fuel, making combustion more efficient.

Standard configuration
SpaceShipTwo can adopt two different configurations, behaving like a winged plane or a capsule.

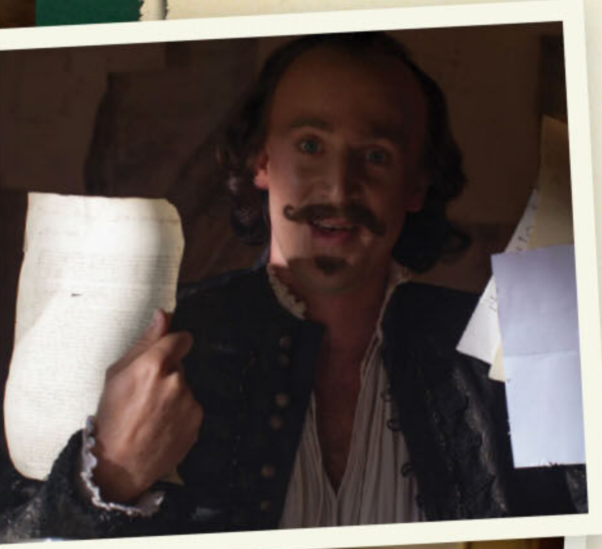
Nitrous oxide tank
The hybrid solid and liquid fuel engine can be shut down during the flight.

> *"We poked, prodded, stretched, squeezed, bent and twisted everything"*

Virgin Galactic hopes to take tourists on short trips to space

© Virgin Galactic; Illustration by Adrian Mann

Greg Jenner is the historical consultant for BBC's *Horrible Histories*



Dressing up is all part of the fun for the *Horrible Histories* team

Horrible Histories'

Greg Jenner

The BBC sketch show's chief nerd separates fact from fiction and shares his favourite revolting stories

From ghastly murders to disgusting diseases, children's TV series *Horrible Histories* features some of the most grisly moments from history, and every single one of them actually happened. We know this because, as a historical consultant for the show, self-confessed history nerd Greg Jenner is in charge of all the facts, and he considers himself a bit of a pedant when it comes to accuracy.

His love of teaching the public about the real-life stories behind historical dramas has gained him over 25,000 followers on Twitter and now he has written his first book about the history of everyday life. *A Million Years In A Day* explores the evolution of our daily routines, from the moment we wake up to when we climb into bed. We interrupted Jenner's daily routine to talk about his personal history highlights, from being smeared in poo to playing a photogenic corpse.

As a historical consultant, do you get annoyed by historical inaccuracies in TV shows and movies?

I don't actually think it's their job to be accurate. It's lovely when they try, but that's not what they're there for. They are meant to be entertaining, so that's why I think it's important that historians tell people after the show has gone out what is true and what isn't. My one bugbear though, the thing that people laugh at me for, is Viking helmets with horns on them. That's the one thing I always get angry about because it's a total myth, but everywhere you go you see the Viking horns and that makes me quite upset.

What's your favourite history myth?

The most common one is that medieval people were covered in filth all the time, that they were just smeared in goat poo, and didn't wash and had horrible teeth, but actually that's not really true. In the Middle Ages people washed quite a lot. They didn't understand germs and did die of some horrible diseases, but they weren't constantly smeared in poo and actually they had quite good teeth in the Middle Ages, because there wasn't really any sugar in their diet. It's not until the 18th century that teeth became awful because people were drinking lots of sugar in their tea.

Which historical mystery would you most like to see solved?

The classic is Atlantis, which is probably a myth, but if they found that it would be lovely. It would also be great to know more about William Shakespeare. He was such an amazing writer and yet we know so little about him, so it would be amazing to find Shakespeare's diary or something.

You have had a few cameos in *Horrible Histories* – which character has been the most fun to play?

Basically I look like a peasant so I'm always deployed in the background as 'Idiot Number 2'. My favourite cameo was when I played a corpse who was having his photo taken. In the 19th century there was a strange fashion where if a family member died, you would take a photo with them before they started to rot away. It was called a 'memento mori' or 'death reminder'. As soon as they died, you would take them down to the photo studio and they would be propped up with a rigid iron spike in the back of their jacket and you would have a photo with them. So I had to sit completely still for about 45 seconds, which is really hard, and then I had to do a comedy tumble off the chair as a dead person would. It was much harder than it looked!

Do you get to keep the costumes?

I would love to. The most beautiful costumes are the 18th century aristocratic ones. As soon as you put them on you find yourself swishing around. It's a very elegant way of dressing.

Greg's mission is to get young people interested in the past

> "I think Oscar Wilde would have been great on Twitter"

I would love to have taken those home, but I'm afraid they all go back to the costume hire company for someone else to use.

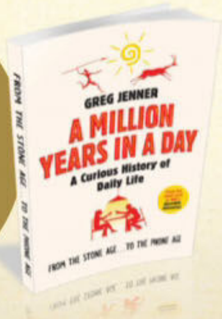
Have there been any moments on *Horrible Histories* where you've had to downplay the horribleness?
Not really no, because the kids love the gore. We've covered Vlad the Impaler, who impaled 40,000 people on spikes to use them as a human fence, and that's pretty much the worst thing you could possibly do as a human. We've done Mary Queen of Scots' beheading, Roman saints being rolled down a hill in a barrel full of spikes and lots of horrible amputations and diseases. There were so many terrible ways to die in the past, and children find them all fascinating.

As a big fan of Twitter, which historical figures would you most like to see have a Twitter feud?
I think Oscar Wilde would have been great on Twitter. Not just because he was so funny and witty, but because he often stole other people's jokes and that's quite common on Twitter. I imagine there would be quite a lot of arguments between people like the great American inventors Thomas Edison and George Westinghouse, as they squabbled a lot.

I reckon many of the people we think of as being wise figures from history, like Abraham Lincoln and the great philosophers would probably just Tweet about their lunch and be as boring as we are!

In your book, *A Million Years In A Day*, you look at the history of our daily routine. Are there any rituals from our historical daily routine that you think should be brought back?
What was quite surprising about the past is that until the 14th century, timekeeping was quite different. An hour was about 45 minutes long in the winter and 75 minutes long in the summer, because there is more daylight in July than there is in December. I quite like the idea of having shorter hours in winter so that we can go to bed earlier and not work as much, and having more time in the summer to spend with our friends and have barbecues.

Greg Jenner's *A Million Years In A Day: A Curious History of Daily Life* is out now. Read our review on page 90!

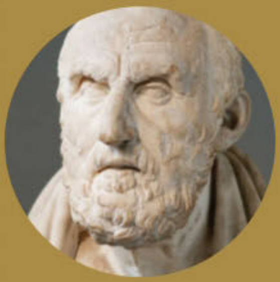


GREG JENNER
A MILLION YEARS IN A DAY
A Curious History of Daily Life
FROM THE STONE AGE... TO THE PHONE AGE

Greg Jenner's top three stupid deaths from history

Clement Vallandigham
Died: 1871
While trying to prove that his client couldn't have been the killer in a murder trial, American lawyer Vallandigham took a gun into the courtroom. In the process of trying to show what happened, he accidentally shot himself and died.

Chrysippus of Soli
Died: 206 BCE
Normally a very serious and stoic Greek philosopher, Chrysippus got his pet donkey drunk on wine and found the sight of it stumbling around and falling over so hilarious that he died in a fit of laughter.



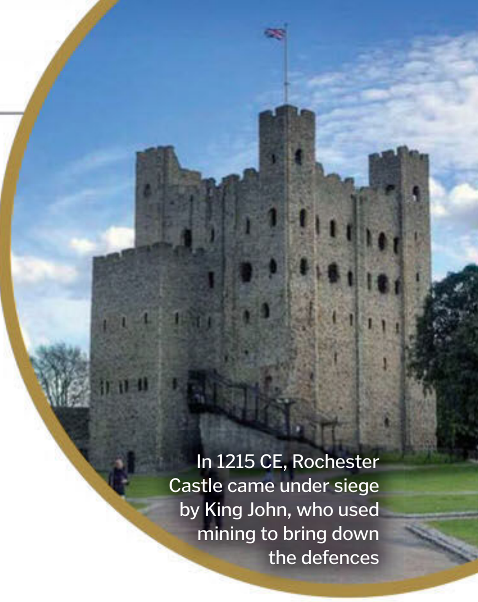
Molière
Died: 1673
The French playwright and actor was playing the lead in his own work, *The Imaginary Invalid*, when he collapsed and died. The character he was playing was a hypochondriac, who thought he was dying but wasn't.

© WIKI

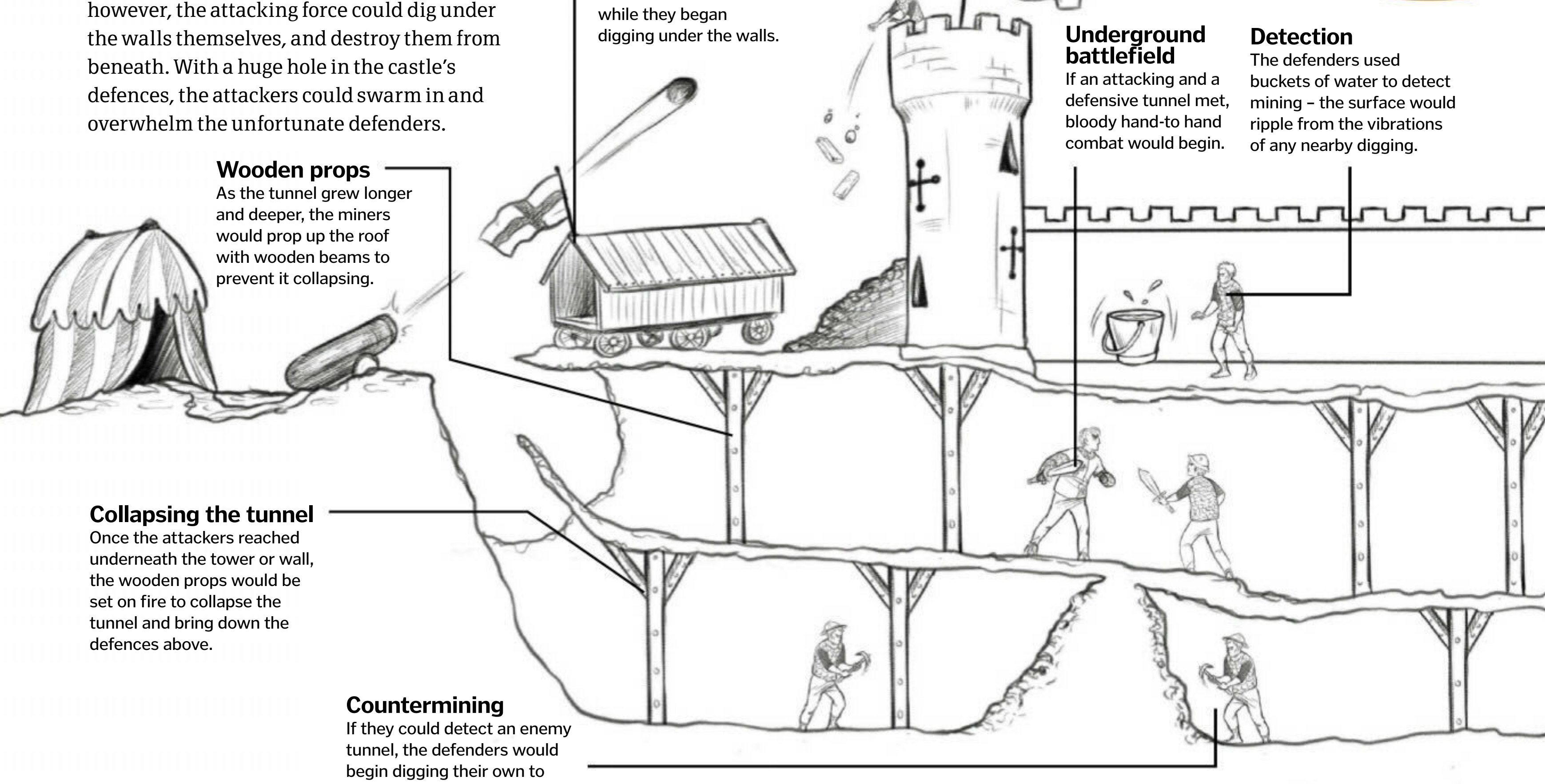
Medieval siege mining

If a castle proved resistant to attack, every good commander knew he could literally undermine its defences

In Medieval warfare there were many ways to bring a fortress crashing to its knees. Battering rams, trebuchets, ladders, or simply starving the garrison into submission were all perfect tools and tactics for winning a siege. If none of these usual methods worked, however, the attacking force could dig under the walls themselves, and destroy them from beneath. With a huge hole in the castle's defences, the attackers could swarm in and overwhelm the unfortunate defenders.



In 1215 CE, Rochester Castle came under siege by King John, who used mining to bring down the defences



Solid defence
Defenders would hurl boiling tar, water and rocks, as well as shoot arrows down onto the attacking force.

The 'cat'
A strong wooden structure, known as a 'cat', would shield the miners from attack while they began digging under the walls.

Underground battlefield
If an attacking and a defensive tunnel met, bloody hand-to hand combat would begin.

Detection
The defenders used buckets of water to detect mining – the surface would ripple from the vibrations of any nearby digging.

Wooden props
As the tunnel grew longer and deeper, the miners would prop up the roof with wooden beams to prevent it collapsing.

Collapsing the tunnel
Once the attackers reached underneath the tower or wall, the wooden props would be set on fire to collapse the tunnel and bring down the defences above.

Countermining
If they could detect an enemy tunnel, the defenders would begin digging their own to intercept and stop the attackers.

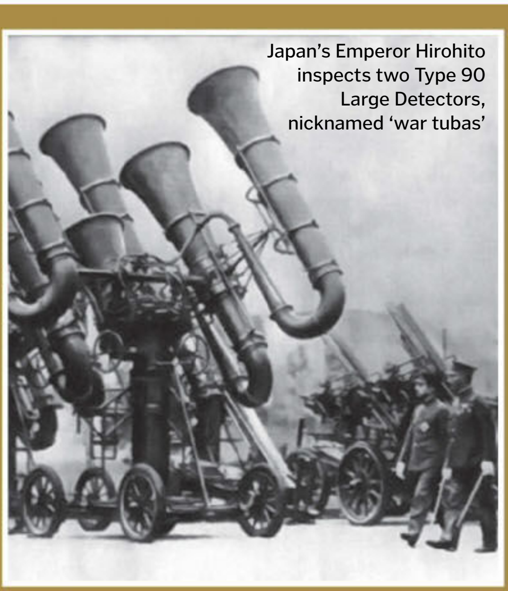
Military acoustic locators

These huge listening devices could hear the enemy coming before they came into view

Before the development of radar, there was only one reliable method for detecting enemy aircraft from far away: to listen carefully. Devices known as acoustic locators were developed to intercept the sound of an approaching aircraft. The sound would travel down an attached cable and into the earphones of the operator, just like a doctor's stethoscope.

Hundreds of different designs were developed during and after World War I, ranging from smaller portable equipment, to devices resembling massive trumpets. At the time, aircraft were relatively slow and their engines loud enough that their approximate direction and elevation could be detected from a distance.

As enemy bombing raids increased over the south of England, huge 'acoustic mirrors' were built to provide early warning of approaching aircraft. These large concrete structures looked like stone satellite dishes, and were designed to capture the engine noise of incoming German zeppelins. However, with the invention of radar and the development of faster aircraft, these structures and acoustic locators became obsolete.



Japan's Emperor Hirohito inspects two Type 90 Large Detectors, nicknamed 'war tubas'

Though some Paracas were found in expensive clothing and jewellery, others were far more simply dressed, and presumably of a lower social status

Ancient Peruvian burials

The Paracas people predate the Incas, but even more unbelievable is what they left behind

For ancient civilisations, giving the dead a proper burial was absolutely essential to ensure the deceased could pass into the next life with safety, dignity and even a bit of style. In ancient, pre-Inca Peru, funeral arrangements took on a bizarre fashion.

The Paracas people lived from around the 8th century BCE until the 3rd century CE. For at least some of this time, they buried their dead wrapped in layers of textiles woven from alpaca wool and cotton. Each piece was decorated with embroidered patterns of animals and humans, and dyed in many colours. The deceased sat within, usually north-facing, in a small basket.

In 1925, Julio Tello found more than 400 graves like this, just south of the city of Pisco in Peru. Each mummified corpse was encased in so many layers of textiles that, from the outside, they appeared like small, conical parcels or bundles. Two Paracas burial sites were identified in Peru, known as the Caverns and the Necropolis. The Caverns site is shaped like a wine glass, with a six-metre shaft leading down to the chamber where the burial bundles are gathered together.

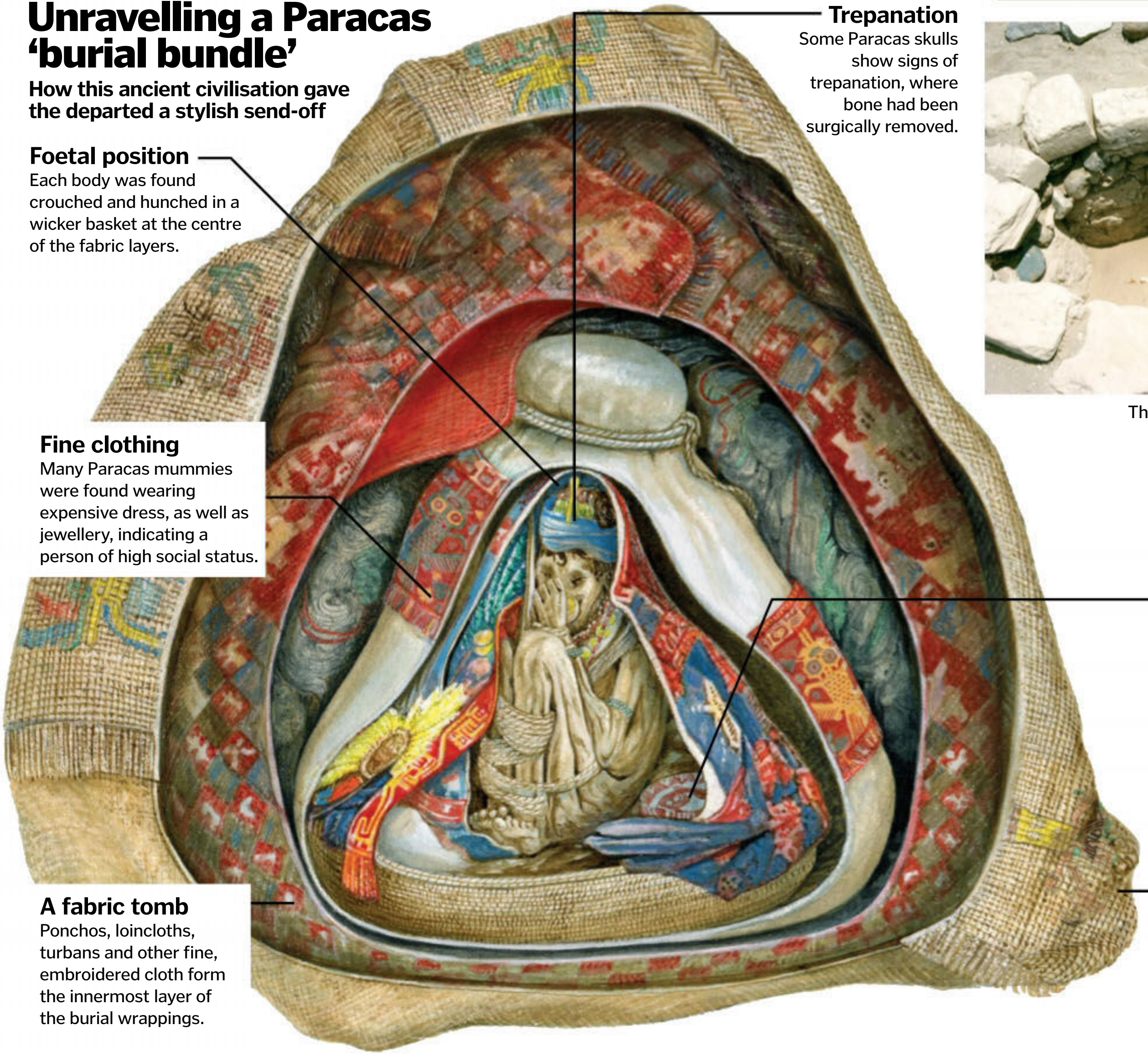
An Ancient Assyrian funeral

During the same period but in ancient Turkey, burial pits were often furnished with turtles and terrapins to accompany the deceased. It's thought the Ancient Assyrians believed these creatures could ward off evil spirits, and act as psychopomps – magical beings to guide the dead person's soul to the underworld. Archaeologists in eastern Turkey recently found evidence of reptilian remains at a burial site dating back to 700-300 BCE, and suspect the unfortunate turtles were even served as funeral snacks first.

The Nazca people of Peru, who lived at the same time as the Paracas, also mummified their dead

Unravelling a Paracas 'burial bundle'

How this ancient civilisation gave the departed a stylish send-off



Foetal position
Each body was found crouched and hunched in a wicker basket at the centre of the fabric layers.

Trepanation
Some Paracas skulls show signs of trepanation, where bone had been surgically removed.

Fine clothing
Many Paracas mummies were found wearing expensive dress, as well as jewellery, indicating a person of high social status.

Personal effects
As well as food and riches, ceramic pots and cups were found within many burials, intricately decorated with depictions of jaguars, birds and snakes.

A fabric tomb
Ponchos, loincloths, turbans and other fine, embroidered cloth form the innermost layer of the burial wrappings.

Outer shell
In some cases, more than 60 layers of cloth were used to complete the 'burial bundle', and ceremonial masks or totems would be attached to the outer layer for prestigious occupants.

© WIKI; Illustration by Art Agency/Sandra Doyle

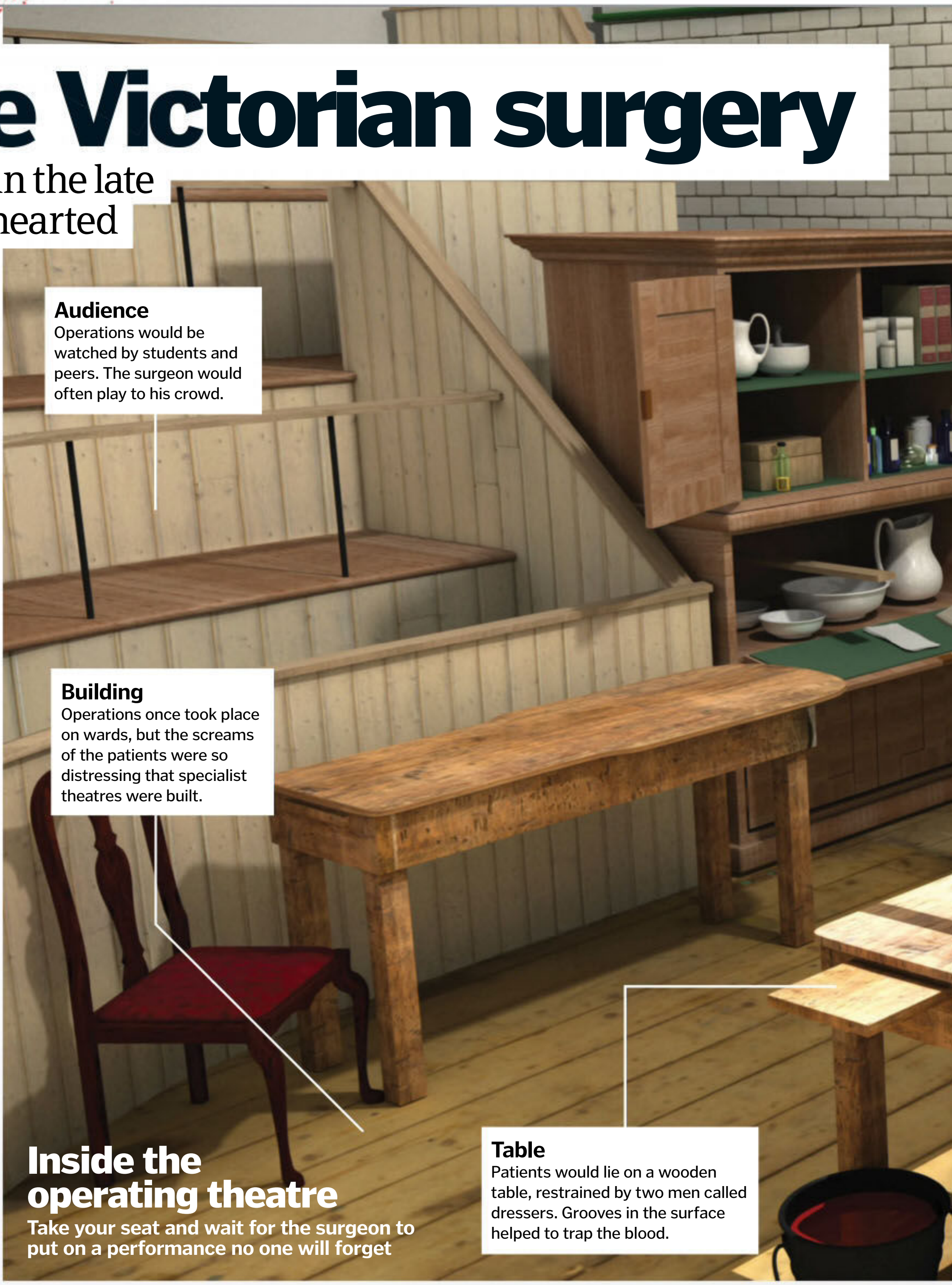
Gruesome Victorian surgery

Being a surgeon or patient in the late 1800s was not for the faint-hearted

The Victorian era has been romanticised for its advancements in science and medicine, but with that came no anaesthetic, poor sanitation and surgeons who didn't even need a qualification to operate. The risk of infection or bleeding to death was so high that surgery was limited to amputations. If you broke a limb, it would have to come off. The surgeon would often perform the procedure in a packed operating theatre, full of students and peers. Rusty saws and knives were the norm, as was the blood-encrusted apron that made the surgeon look more like a butcher than a man of medicine. He would slice through flesh and bone in 30 seconds flat. The faster the better, to prevent the patient from fleeing mid-way through, or worse, dying from shock.

Anaesthesia and painkillers weren't in use until the latter half of the 19th century, and even then they were very rudimentary. Alcohol was always an option, to get the patient drunk enough to numb the pain. Chloroform and ether were also used as early anaesthetics, but both were dangerously potent, and ether was also highly flammable – rather hazardous for use in theatres that were lit by naked flames.

One of the major advances in surgery was in 1867, when Joseph Lister pioneered aseptic techniques and began to sterilise wounds, operating theatres and instruments using carbolic acid. He even experimented with hand washing, which had previously only been performed *after* an operation! This lowered infection, and Lister eventually became known as the 'father of antiseptic surgery'.



Inside the operating theatre

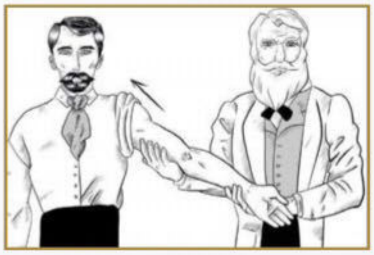
Take your seat and wait for the surgeon to put on a performance no one will forget

Audience
Operations would be watched by students and peers. The surgeon would often play to his crowd.

Building
Operations once took place on wards, but the screams of the patients were so distressing that specialist theatres were built.

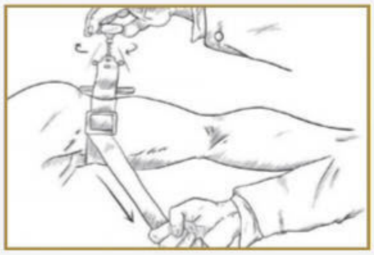
Table
Patients would lie on a wooden table, restrained by two men called dressers. Grooves in the surface helped to trap the blood.

A step-by-step guide to amputation



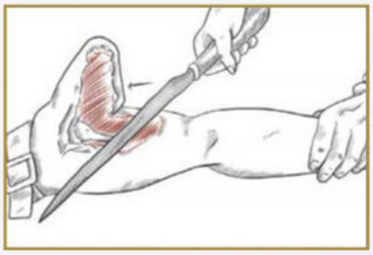
1 Prep the patient

Patients were laid on an operating table, and warned to keep very still, often without any anaesthetic or painkillers. The slightest movement could botch the operation and result in death.



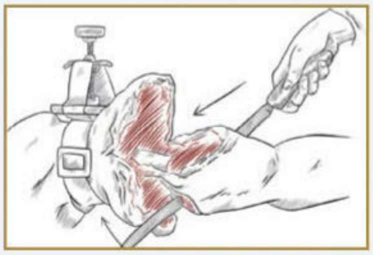
2 Tighten the tourniquet

To stem the flow of blood, tourniquets were placed above the incision. These were made of canvas straps that were tightened using a screw attached to brass plates on either side.



3 Make the first incision

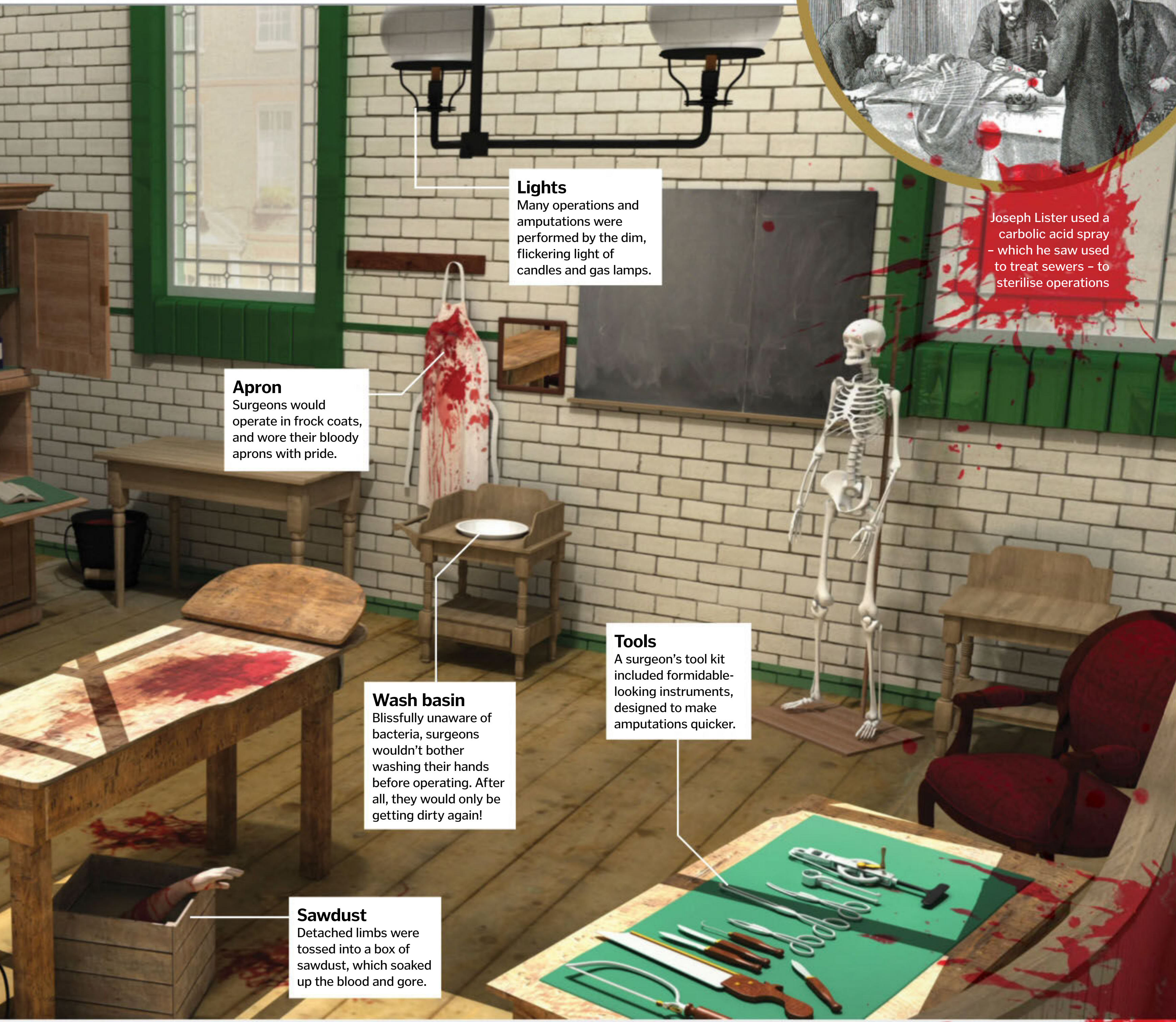
Surgeons would use large knives, often with curved blades. The first incision would slice through the flesh and muscles that were around the bone in a circular motion.



4 Make the second incision

This process was then repeated on the other side of the limb. It was called the 'tour de maitre', or 'turn of the master', and it had to be performed very quickly for the patient's sake.

DID YOU KNOW? *The Archbishop of Canterbury could grant medical licenses until 1858*



Lights

Many operations and amputations were performed by the dim, flickering light of candles and gas lamps.

Joseph Lister used a carbolic acid spray – which he saw used to treat sewers – to sterilise operations

Apron

Surgeons would operate in frock coats, and wore their bloody aprons with pride.

Wash basin

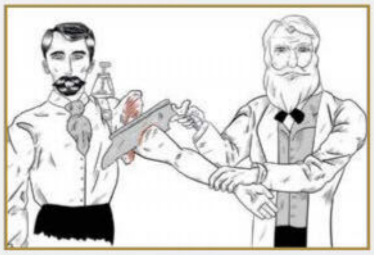
Blissfully unaware of bacteria, surgeons wouldn't bother washing their hands before operating. After all, they would only be getting dirty again!

Tools

A surgeon's tool kit included formidable-looking instruments, designed to make amputations quicker.

Sawdust

Detached limbs were tossed into a box of sawdust, which soaked up the blood and gore.



5 Saw the bone

Using the amputation saw, the surgeon would cut completely through the bone. The detached limb would then be dropped into a bucket of sawdust in order to absorb the blood.

6 Stitch it up

Once the limb was free, the surgeon would stitch up the main artery and smaller blood vessels. When the blood eventually stopped flowing, he would begin to stitch up the wound.

7 Bandage it up

The stump would be dressed in bandages. This had to be done carefully, because bandages that were either too loose or too tight could cause issues with the healing process.

8 Apply final touches

Once the procedure was finished, the patient would be taken away for recovery. Some 25 per cent of amputees would not survive, as poor sanitation often led to deadly infections.

© WIKI

BRAIN DUMP

Because enquiring minds need to know…

Want answers?

Send your questions to…

How It Works magazine
@HowItWorksmag
howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

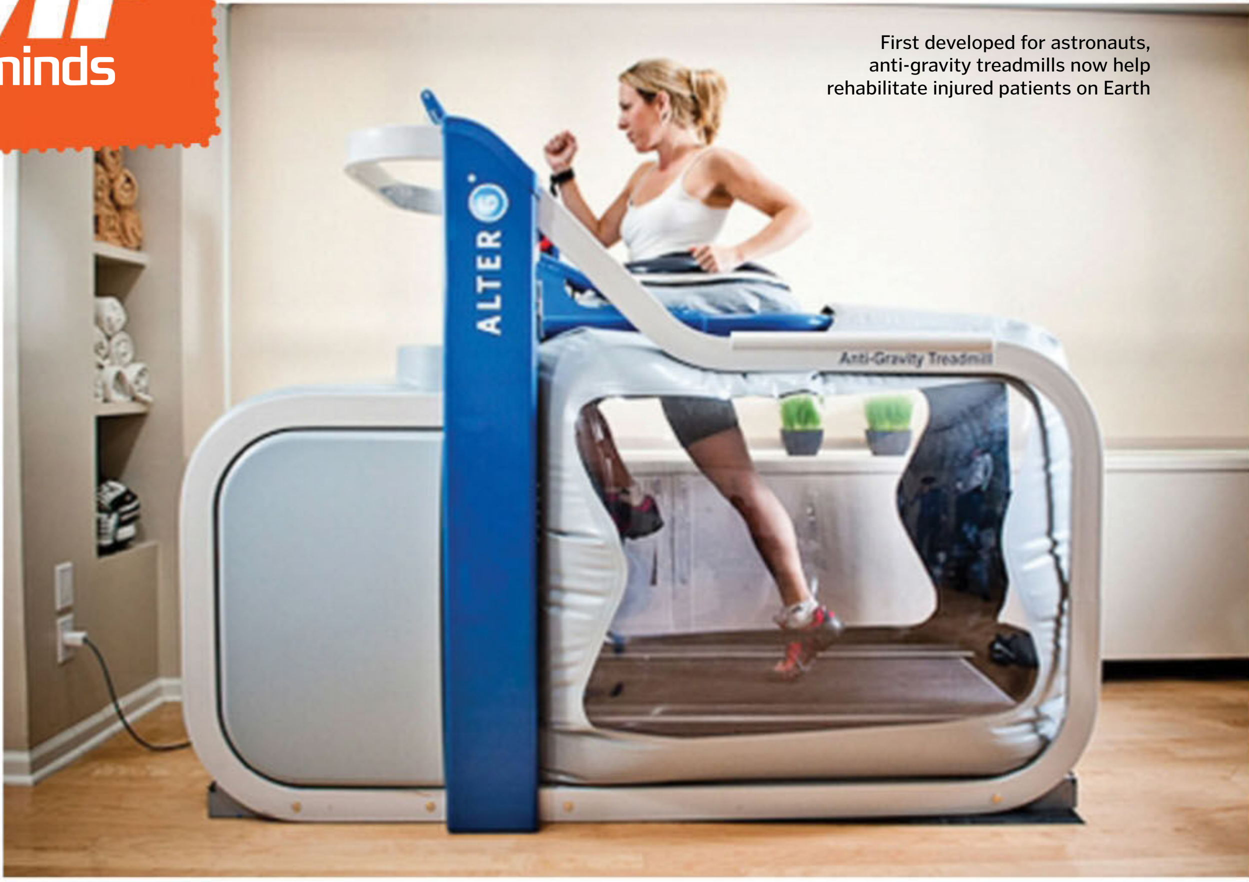
Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds that her job comes in very handy for taking part in quizzes!

Gemma Lavender

Gemma is the Editor of **All About Space**. She holds a master's in astrophysics, is an elected fellow of the Royal Astronomical Society and an associate member of the Institute of Physics. She is a STEM Ambassador and has been a keen observer of the night sky for more than 15 years.



First developed for astronauts, anti-gravity treadmills now help rehabilitate injured patients on Earth

How do anti-gravity treadmills work?

Chris Devine

An anti-gravity treadmill encloses the user's lower body in an airtight chamber, altering the air pressure to either re-create the effects of gravity, or conversely to counteract gravity. The user is zipped into an airtight compartment, the upper surface of which incorporates a snug-fitting pair of shorts. By reducing the air pressure inside the chamber, the person is pulled downwards. The technology was first developed for NASA, to allow astronauts to replicate our planet's gravity while exercising in space, but the design was never implemented. Instead, it has become popular on Earth, where the machine's working is reversed. The chamber is inflated to lift the runner so that they are not bearing their full weight. This makes the anti-gravity treadmill a useful tool for rehabilitation, allowing patients to exercise without placing strain on joints, while recovering from injury for instance. **AC**

It's widely believed that GI originally stood for galvanised iron

Why are American soldiers called GIs?

Amelia Evans

The reason behind this name is not totally clear, but the most widely believed theory dates back to the beginning of the 20th century, when the letters 'GI' were stamped on military trash cans and buckets to show they were made of galvanised iron. The theory goes that it was then used to refer to all things related to the army in World War I, but the meaning of the letters changed to 'government issue' or 'general issue'. By the time World War II occurred, soldiers were referring to themselves as GIs. US toy company Hasbro created the popular GI Joe doll in 1964, and the nickname has stuck ever since. **SB**

New technologies have made it safe to use mobile phones on flights

Why can't you use your phone on airplanes?

Andy Moffat

■ Many airlines now allow travellers to use phones in-flight following a relaxing of regulations. Previously, there were concerns that radio signals emitted by phones could interfere with aircraft communications, flight control or other onboard electronic equipment. There was never clear evidence of this, but the introduction of new technologies has minimised the risk of interference further. Picocell devices act as a mini cell tower on a plane, collecting signals from phones on board and beaming them down to a communications satellite or base station on the ground. **AC**

Gorillas can grip with their feet as well as their hands

What are toenails for?

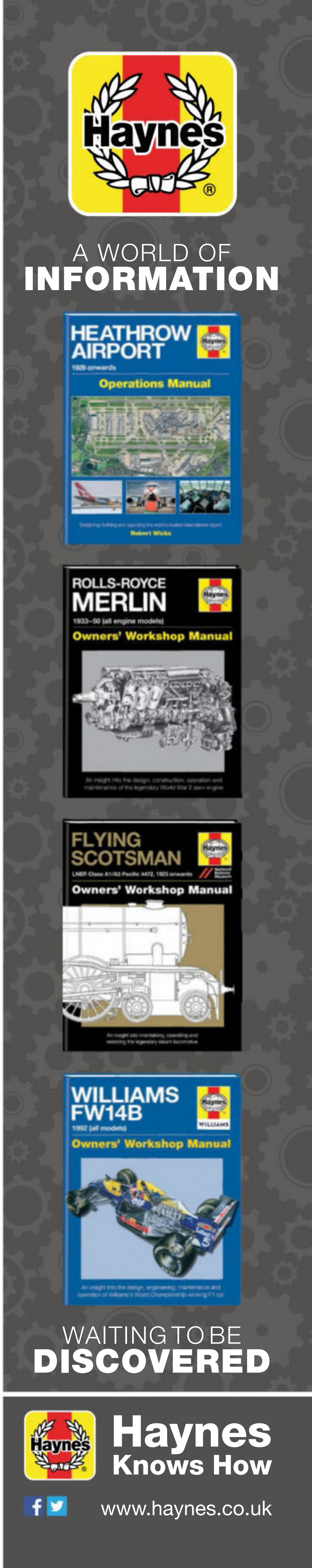
Luke Howard

■ Toenails may help us to balance when walking, but they may also just be an evolutionary leftover from when we walked on all fours. Fingernails and toenails are a primate's version of claws, and are part of what set us apart from other mammals. Some researchers believe that claws flattened into nails as primates evolved broader fingertips. This likely happened around the same time that early humans started using stone tools. The need for fingernails seems a little more obvious when you need to tear apart food or grasp something, and all primates – with the exception of humans – can do this with their feet as well. **SF**

Why did the Egyptians build the Great Sphinx?

Anja Arends

■ Sphinx statues were built in Ancient Egypt to guard important areas. The Great Sphinx of Giza is thought to have been built during the reign of Pharaoh Khafre, between 2520 and 2494 BCE. There was a trend for large stone architecture, but instead of using stone blocks, the Great Sphinx was carved out of a single, enormous mass of limestone. It's believed to be part of a set of structures that were built to associate the dead king with the Sun god. **SB**



A WORLD OF INFORMATION

WAITING TO BE DISCOVERED

Haynes Knows How

www.haynes.co.uk

Give up? Then wave something white to signal your surrender

When did the white flag become associated with surrender?

Ben Appleby

Surrendering with the white flag is at least as old as China's Han Dynasty, dating to 25 to 225 CE, but it probably began even earlier. Roman historian Cornelius Tacitus also wrote about them in 109 CE, referencing white-flag use in a battle that took place 40 years earlier. White fabric was probably used because it was the easiest to obtain, and it also stood out against the landscape and other more colourful flags on the battlefield. Today using a white flag as a symbol of ceasefire, surrender or negotiation is part of the Geneva Convention. **SF**

Hearing words or smelling scents while sleeping can help to reinforce memories

Is it possible to learn a language while you're asleep?

Matt Drage

Maybe! There is evidence to suggest that non-rapid eye movement sleep is an important time for memory consolidation; patterns learnt during the day are reactivated and strengthened at night. In 2014, researchers from Switzerland published results of a study that tested whether playing words during this crucial sleep period could help to trigger these reactivation patterns, assisting with learning. They took 68 healthy volunteers and taught them 120 pairs of words, one in their native language, and the other in a language that they did not know. They were then split into groups, with some of them being played the word pairs again as they slept that night, and others sleeping in silence. When they woke up, the group who had been replayed the words in their sleep were much better at translating them. Unfortunately though, this method only seems to work to consolidate memories. You can't press play on a language tape, fall asleep and wake up fluent – you must do the groundwork while you're awake. **LM**

FASCINATING FACTS

Who invented the Western-style toilet?

Plumber and toilet salesman Thomas Crapper is often mistakenly given the credit, but the first flushing toilet was actually invented by Sir John Harrington in 1596. **SF**

The flushing toilet didn't catch on until Alexander Cummings invented the S-bend in 1775

How many atoms are there in the human body?

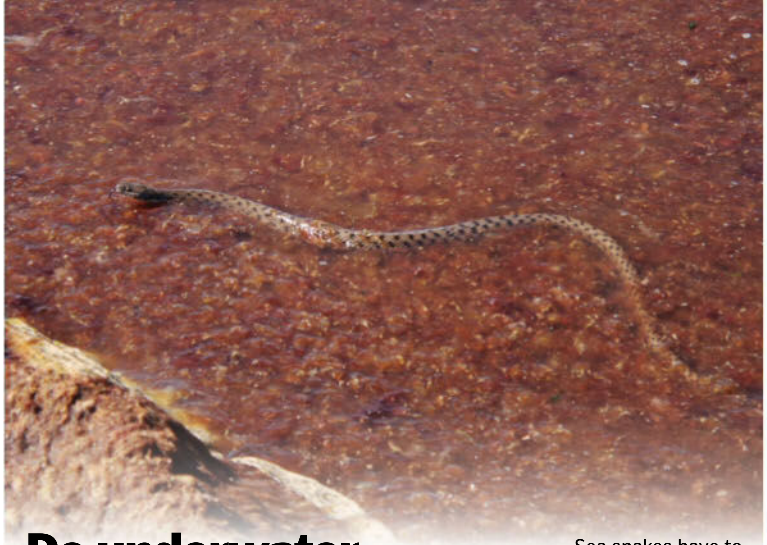
The human body is mostly made up of hydrogen, oxygen and carbon. An average 70-kilogram adult contains around seven billion billion billion atoms (that's seven with 27 zeros after it!). **LM**

There are trillions of carbon atoms in the human body

What is the rarest element on Earth?

The rarest naturally occurring element on Earth is astatine, a radioactive semi-metal. Produced by the decay of heavier elements, there are less than 30 grams of it in existence at any one time. **AC**

Astatine is formed in the Earth's crust and has a very short half life



Sea snakes have to surface occasionally in order to breathe

Do underwater snakes have gills?

Joseph Newell

■ While some snakes spend time in water, sea snakes live there permanently. However, instead of gills, they have a single lung, and must surface to breathe about once an hour. Valves keep their nostrils, which sit on top of their snouts, closed the rest of the time. These snakes also absorb oxygen through their skin, and have small, flattened heads, and paddle-like tails to aid with swimming. Most species live in warm waters in the Indian and Pacific Oceans. Sea snakes have very potent venom and release small amounts when biting fish and other prey. **SF**

Would polar bears be able to survive in Antarctica?

Isabelle Durand

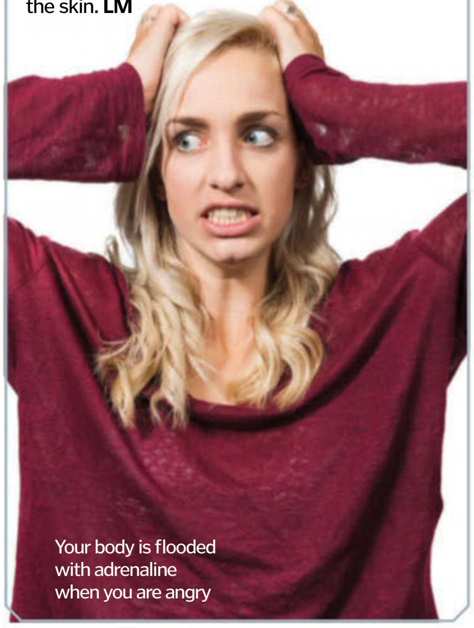
■ Discussions have taken place on relocating polar bears to Antarctica to aid their survival, due to significant sea-ice loss in the Arctic. However, although polar bears probably *could* survive in Antarctica, the disadvantages outweigh the advantages. Scientists have studied previous cases where animals have been relocated, and found that it's usually harmful to the overall ecosystem. Seals and penguins currently have no land predators in Antarctica, but this would change if polar bears were introduced to their habitat – it could even result in their extinction. Throughout the food chain, the balance of resources such as space, water and food would be upset, and polar bears could introduce new diseases to native species, or face life-threatening diseases themselves. So although polar bears would probably survive in Antarctica, the move would be counterproductive. **SB**

Polar bears could survive in Antarctica but the relocation process would be disastrous

Why does your face turn red when you're angry?

Rob Lewis

■ Anger can trigger the fight-or-flight response – an in-built biological reaction that prepares your body to stand up to a threat, or to run away. The body is flooded with two chemical messengers: adrenaline and noradrenaline. They make the heart beat faster, open small airways in the lungs, and increase the rate and depth of breathing. They also trigger the release of sugar into the blood, and increase the delivery of oxygen to your muscles and brain. All of this can help to prepare you for confrontation, but it does have its side effects, and one can be flushing. Adrenaline can cause the blood vessels in the face to get wider, increasing blood flow to the skin. **LM**



Your body is flooded with adrenaline when you are angry

Uneven weight distribution makes an unconscious person harder to carry

Why do unconscious people feel much heavier?

Matt Williams

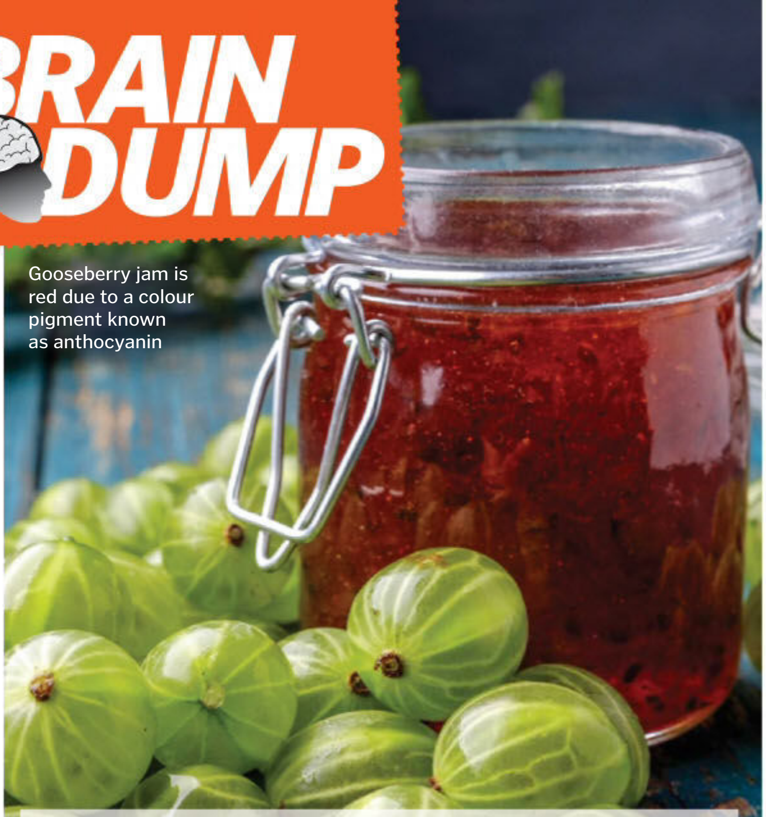
■ When a person's muscles are totally relaxed, their weight is distributed unevenly over a wider area. A conscious person will usually tense their muscles when lifted, keeping limbs in or putting their arms around the neck of the person carrying them. This makes the carrier's job easier, as the centre of mass is focused centrally. An unconscious person is limp, allowing their arms and legs to swing around and causing their centre of mass to shift erratically. A fireman's lift allows the carrier to grip the unconscious person better and manage their weight distribution. **AC**

Do you burn calories just by thinking?

Lucy Young

■ Absolutely. In fact, thinking is an extremely energy-intensive process, and your brain consumes around 20 per cent of your calories every day. Unfortunately, however, thinking extra hard doesn't really burn more calories than usual. Some studies have shown that thinking hard actually causes a dip in your blood-sugar level as your brain takes in more energy, but it's nothing compared to the amount of energy that your muscles use when you move. The brain consumes around ten calories per hour, whereas an activity such as running can drain more than 300. **LM**

Thinking does burn calories, but it's nowhere near as effective as exercise


Gooseberry jam is red due to a colour pigment known as anthocyanin

Why is gooseberry jam red when gooseberries are green?

Adrian Robinson

The gooseberry is a round, edible berry with a thin, translucent, hairy skin. Although green in colour, gooseberry jam is a shade of orange or red due to a pigment in the berry called anthocyanin. This pigment is present in many fruits, and can give them reddish, yellow or green colours, depending on the pH, or acidity, of the fruit. When you cook a gooseberry jam mixture, the anthocyanins are heated and come into contact with plant sugars such as pectin, as well as metal ions from cooking instruments. This process is thought to change the acidity and slightly alter the structure of the anthocyanins, and the jam changes colour as a result. **SB**

'Honeymoon' conjures images of newlyweds in exotic locales, but this wasn't always the case

Where did the idea of honeymoons come from?

Amy Lippiatt

Today a honeymoon is a holiday during which a married couple spends post-wedding time together. The origin of the phrase may be more sceptical than sweet though. Writers in England in the mid-1500s used 'honeymoon' to warn newlyweds that the happy period immediately following marriage might not last longer than the waning Moon. The idea of going on a holiday after marriage began in the 1800s. Originally limited to upper-class couples, they mostly travelled to visit family members who couldn't make the wedding. The rise of mass tourism meant that more couples went on honeymoons – and travelled alone. Some historians believe that the term refers to a couple traditionally drinking mead, a liquor made from honey, during the first month of marriage, but not everyone buys into this origin. **SF**

Grey hair can become dry and coarse

Why are grey hairs thicker than non-grey hairs?

Suzy Hall

Interestingly, grey hairs aren't actually thicker than non-grey hairs. In fact, hair tends to get thinner and finer as we age. Grey hairs just appear thicker because they are more fragile and prone to drying out. As we get older, individual strands of hair begin to lose their pigment. At the same time, the scalp starts to produce less of the oily fluid sebum. Without this natural moisturiser, the strands easily become dry, and the cuticle that covers the outside of each hair can become rough. This roughness can make the hairs feel thicker, cause kinks to form, and reduce shine. **LM**

Why does wet paper stick together?

Stephen Oswald

A property called cohesion makes water molecules stick to each other, which in turn holds wet sheets of paper together. Cohesion stems from the fact that water molecules are polar, with one end carrying a partial negative charge, while the other has a partial positive charge. This means that water molecules form hydrogen bonds with their neighbours. When you wet a sheet of paper, water molecules are absorbed among the cellulose fibres of the paper. The water molecules also cling to each other, acting as a weak 'glue' holding the two pieces of paper together. The same effect can be observed with wet hair or even wet sand. **AC**

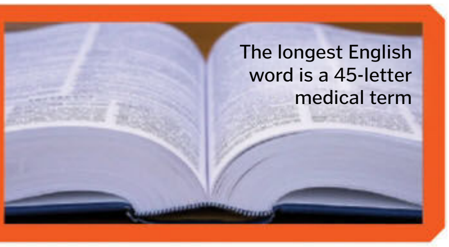
Cohesion between water molecules causes wet paper, hair or sand to stick together

FASCINATING FACTS

What is the longest English word?

Charlotte Walker

It is pneumonoultramicroscopicsilicovolcanokoniosis, which is a lung disease caused by inhaling fine ash and sand dust. Understandably, it's not widely used! **SB**


The longest English word is a 45-letter medical term

ASK THE ASTROPHYSICIST

Astronomy top tip
Use a red flashlight when looking at star maps in the dark in order to preserve night vision

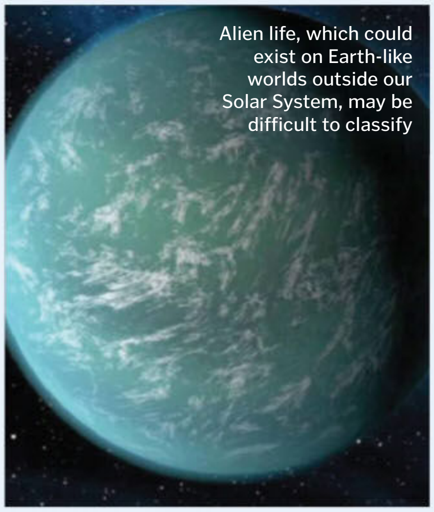
Gemma Lavender
Gemma is the Editor of **All About Space.**

Heat shields protect spacecraft when entering a planet's atmosphere

Why do spacecraft only need a heat shield for re-entry, not launch?

Caroline Robertson

■ The heat experienced by spacecraft as they enter an atmosphere is caused by friction against atmospheric molecules, exacerbated by speed. During atmospheric entry, it plunges into thicker atmosphere, so friction and heat increase, reaching over 1,600 degrees Celsius, until it slows down. When a spacecraft launches, it works against gravity. Once it has built up speed, it's already above the thickest part of the atmosphere, so there is less friction and heat. Also, when a spacecraft launches on a rocket, it's often housed in a protective shroud that splits in two to release the spacecraft once in space.

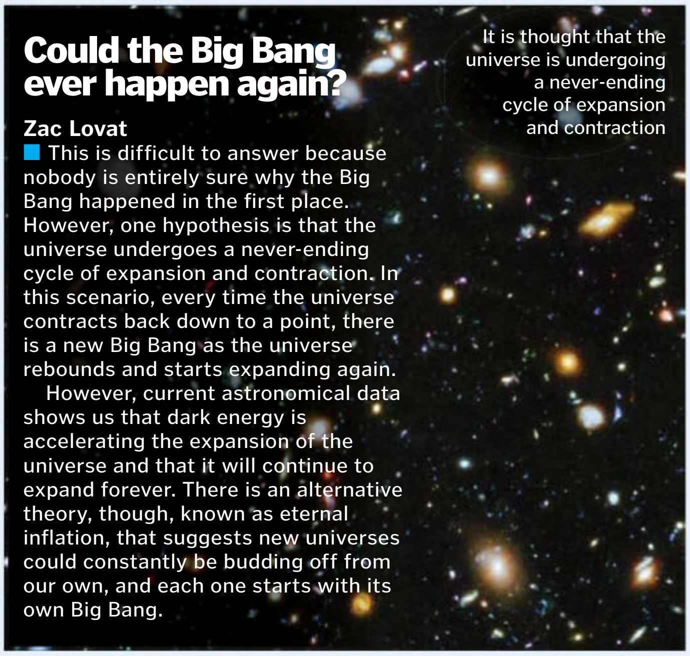


Alien life, which could exist on Earth-like worlds outside our Solar System, may be difficult to classify

If we found alien life, how would we classify it?

Anon via email

■ The temptation might be to classify alien life in the same categories that we do on Earth – plant, animal, reptile, mammal, avian and so on – but alien life could surprise us by being completely beyond our expectations! It is difficult to say exactly what alien life will be like because it will not necessarily have evolved in the same way as life has on Earth. However, there are several broad categories that alien life might fit into. The simplest categories are microbial life and more complex life-forms, and they may have varying degrees of intelligence. Beyond that, astrobiologists tend to look for planets that may have an oxygen-rich atmosphere, but alien life could have different chemistries, and breathe in and out different gases instead. For instance, if there were life on Saturn's moon Titan, it would be methane-based. Plus, there's always the possibility that alien life might be so alien that we don't even recognise it as being alive!



It is thought that the universe is undergoing a never-ending cycle of expansion and contraction

Could the Big Bang ever happen again?

Zac Lovat

■ This is difficult to answer because nobody is entirely sure why the Big Bang happened in the first place. However, one hypothesis is that the universe undergoes a never-ending cycle of expansion and contraction. In this scenario, every time the universe contracts back down to a point, there is a new Big Bang as the universe rebounds and starts expanding again.

However, current astronomical data shows us that dark energy is accelerating the expansion of the universe and that it will continue to expand forever. There is an alternative theory, though, known as eternal inflation, that suggests new universes could constantly be budding off from our own, and each one starts with its own Big Bang.

Who is able to see a black hole?

Tanya Burton

■ Astronomers can't actually see black holes directly, but they know they are there based on the strength of their gravity, with hot gas often being pulled towards a black hole to form a bright disc around it.

Black holes are visible thanks to discs of hot gas around them

Astronauts flush their waste out into space, where it orbits Earth for a while

What happens to waste from the Space Station?

Robbie Jones

■ The next time you see a shooting star, it could be human excrement. Astronauts on the International Space Station flush their poo out into space, where it orbits Earth before burning up in the atmosphere as a shooting star. NASA astronaut Scott Kelly produced 80 kilograms worth of smelly shooting stars during his recent year-long stay on the Space Station! Regular rubbish is brought back down to Earth on board supply vessels that stop at the ISS.

© Thinkstock; Dreamstime; NASA

What's happening on... Twitter?

Join **All About Space** every Saturday 6-9pm (GMT/BST) for a Q&A on Twitter where your astronomy questions will be answered live! Tweet your questions to **@spaceanswers** and follow **#StargazerSat**

@gau3tam7
@spaceanswers Did the Black Knight Satellite really exist?

■ This object does exist. However, it is likely to just be a piece of debris from another satellite, such as a thermal blanket.

@Ranran270983
@spaceanswers Would you say there is a specific time of year that is best for stargazing?

■ Winter is best for stargazing due to the longer night hours.

@The_LizMarshall
@spaceanswers What was the first constellation ever to be identified; when was this and who found it?

■ According to writings on clay tablets, Orion is thought to be the first constellation to be identified back in 3000 BCE!

@GeekCliche
@spaceanswers How far out would we need to travel before the constellations seemed visibly distorted to us?

■ Great question! You'd need to travel hundreds, if not thousands, of light years.

Get in touch

Facebook
How It Works magazine

Twitter
@HowItWorksmag

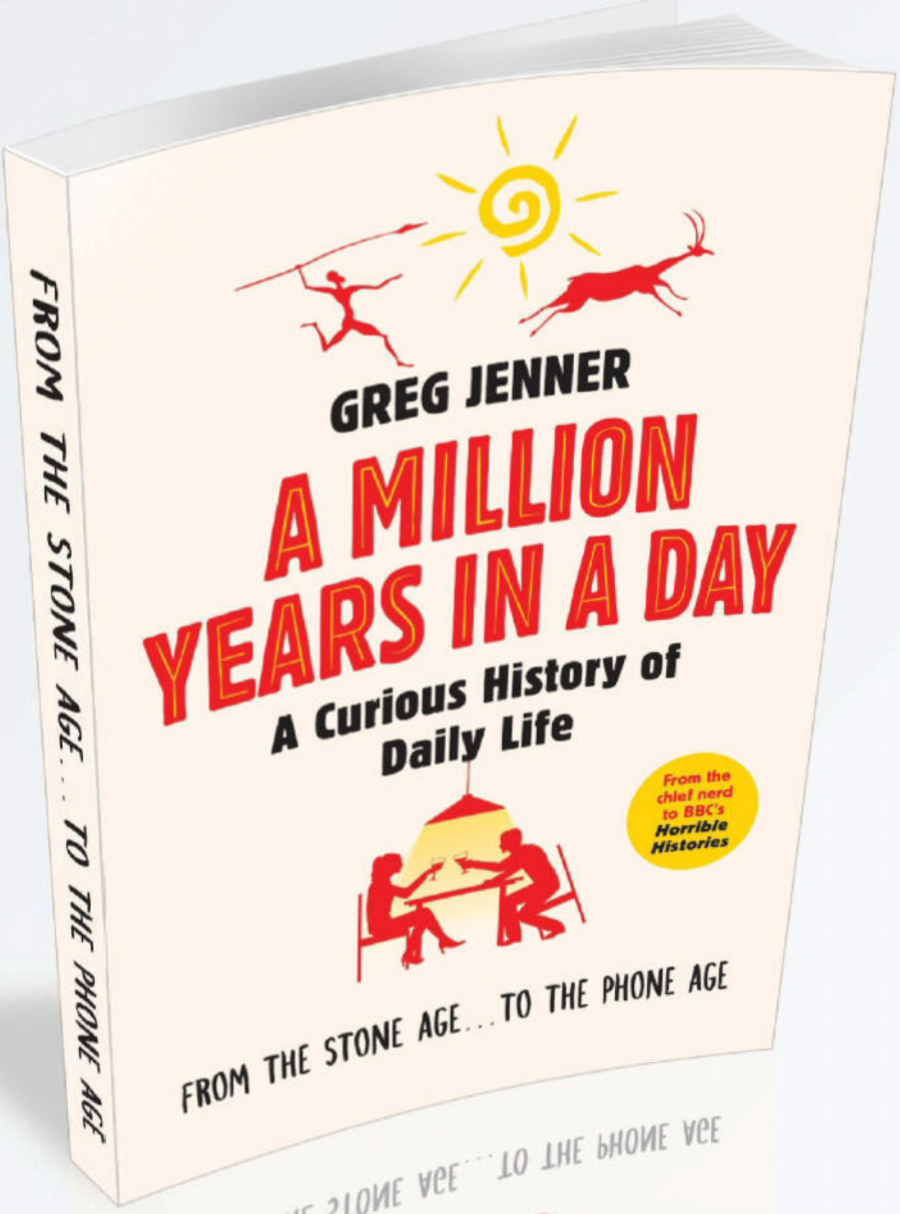
Email
howitworks@imagine-publishing.co.uk

BOOK REVIEWS

The latest releases for curious minds

A Million Years In A Day

Delve into the curious history of everyday life


FROM THE STONE AGE... TO THE PHONE AGE
GREG JENNER
A MILLION YEARS IN A DAY
A Curious History of Daily Life
From the chief nerd to BBC's Horrible Histories
FROM THE STONE AGE... TO THE PHONE AGE

- Author: **Greg Jenner**
- Publisher: **Orion Publishing**
- Price: **£8.99 / $26.99**
- Release date: **Out now**

Most of us go about our daily rituals with little thought as to why we do them, from brushing our teeth to selecting an outfit to wear. Not any more. Read this brilliantly written book and no longer will you take such practices for granted. Greg Jenner not only forces us to stop and think about why our lives are so structured, from the moment we are woken up by an alarm to the time we set said alarm later that night, but also provides a unique insight into how these habits have evolved over time.

Each chapter examines a different part of a typical day, taking a single task and exploring a range of formalities associated with it. For example, when looking at how humans have answered the morning call of nature over the years, Jenner addresses location, hygiene, cleaning materials and a whole host of other candid details.

In doing so he takes us on a journey that spans centuries, through countries and cultures, examining different rituals between rich and poor, men and women. On the one hand, you'll gasp at how shocking some of our everyday customs used to be, but on the other, you will discover that we are really not all that different to our Stone Age ancestors after all.

Jenner unearths some of the most intimate customs in rather graphic detail, leaving little to the imagination. It's like an adult version of CBBC's *Horrible Histories* – for which Jenner is the historical consultant – but here lie some of the most fascinating facts that we may never have even considered!

Like the typical routine Jenner writes about, the structure of *A Million Years In A Day* is just that – structured, and somewhat predictable as you begin each new chapter. However, Jenner's dry sense of humour and quirky imagery prevent it from becoming stale.

It's no mean feat to make a book about the seemingly mundane habits of human beings engaging, fascinating and amusing, and Jenner has well and truly delivered. Also available on audiobook, narrated by the author himself, this would make a great accompaniment for long car journeys.

★★★★★

YOU MAY ALSO LIKE...

History Without The Boring Bits

Author: **Ian Crofton**
Publisher: **Quercus**
Price: **£9.99 / $16.99**
Release date: **Out now**

An unconventional chronology of world history, this book puts monarchs and politics to one side, exploring some of the world's most bizarre facts and legends in a refreshingly entertaining way.

A Short History Of Nearly Everything

Author: **Bill Bryson**
Publisher: **Black Swan**
Price: **£9.99 / $16.99**
Release date: **Out now**

Dealing with a different topic per chapter, Bryson's approach to world history is perhaps more traditional in terms of the subjects it covers, but is accessible and beautifully written.

Sapiens: A Brief History Of Humankind

Author: **Yuval Noah Harari**
Publisher: **Vintage**
Price: **£9.99 / $29.99**
Release date: **Out now**

How did the human race become what it is today? Harari offers a unique explanation that many will find controversial. Read with an open mind and you might look at life in a whole new way.

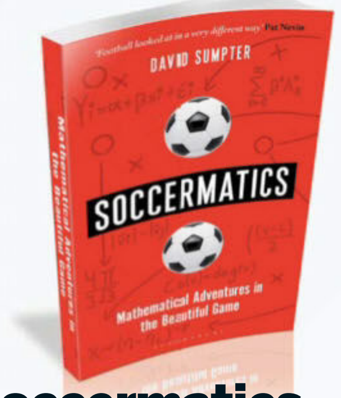
Bletchley Park's Secret Room

An inside look at WWII's code-cracking HQ

- Author: **Joss Pearson**
- Publisher: **Amberley**
- Price: **£7.99 / $13.00**
- Release date: **Out now**

While the author of this book is listed as Joss Pearson, a large portion of it is an original account taken from Major Neil Webster, a key member of the team based in Bletchley Park's Fusion Room. The first-hand report is incredibly insightful – Major Webster explains the workings of the Fusion Room, where codes were cracked and intercepted messages were decoded – and it gives readers a sense of his life during the war. The latter portion of the book is made up of background information, giving details about Major Webster himself and others at Bletchley Park. These are worth a look, although not quite as engaging as the first-hand account of the work being done. Still, it nicely rounds off a genuinely engaging collection.

★★★★☆



Soccermatics

Analysing footie is more complex than it sounds

- Author: **David Sumpter**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27.00**
- Release date: **Out now**

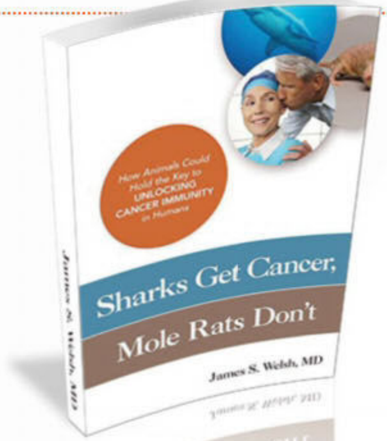
As Sumpter expresses in the introduction to *Soccermatics*, he quite clearly understands that the world of maths can never match that of football for excitement and passion, otherwise "we would be ready to pay £40 a month for a subscription to Sky Mathematics." But it's also clear that the author loves both; as he talks about how maths is in every part of the beautiful game, he drops references to famous seasons, players and teams. For football fans there is plenty to enjoy here, like the analysis of team formations or betting techniques. If you don't care about either subject, this isn't for you, but an interest in either will make this a very entertaining read.

★★★★★

Sharks Get Cancer, Mole Rats Don't

Bringing hope to a tough topic

- Author: **James S Welsh**
- Publisher: **Prometheus Books**
- Price: **£14.99 / $19.00**
- Release date: **Out now**


How Animals Could Hold the Key to UNLOCKING CANCER IMMUNITY in Humans
Sharks Get Cancer, Mole Rats Don't
James S. Welsh, MD

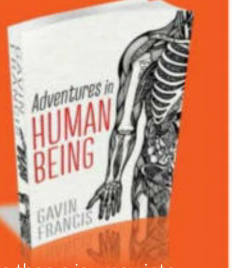
We rarely hear about researchers looking at other species when it comes to fighting cancer, but by the end of chapter one you'll realise that the animal kingdom has a lot to teach us on the subject of immunology. The book regularly trots across the globe, from the Tasmanian marsupials that are dying out due to a form of contagious cancer, to an astonishing lab-mouse that is immune to the disease for reasons completely unknown. The writing style takes some getting used to, as it switches oddly between informal and scientific language, but there are some staggering insights that will give you hope that maybe a cure for cancer isn't all that far away.

★★★★☆

Adventures In Human Being

Looking at the body from the inside out

- Author: **Gavin Francis**
- Publisher: **Profile Books**
- Price: **£8.99 / $26.99 (hardback only in US)**
- Release date: **Out now**



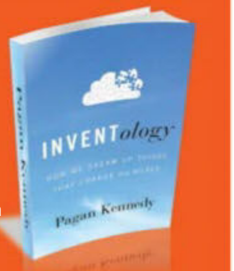
Starting with the brain and ending at the toes, this book is an insightful account of how our bodies work. Author Gavin Francis draws on his experience as a surgeon and family physician, drip-feeding real-life examples with minimal medical jargon. More than a journey into the inner workings of humans, he also examines how people have understood the body throughout history, and how it has been treated. With a novel approach and plenty of trivia (did you know the term 'cataract' means 'portcullis' in Greek – a barrier that clouds vision?) there's enough here to both impress your friends and give a whole new insight into your own wellbeing.

★★★★☆

Inventology: How We Dream Up Things That Change The World

The invention game

- Author: **Pagan Kennedy**
- Publisher: **Bantam Press**
- Price: **£18.99 / £27.00**
- Release date: **Out now**



Ideas. Everyone has them – some inspired, some not so much – but how do we come up with them in the first place? Is it something that can be taught, or is it an entirely natural process? That's what Pagan Kennedy is here to find out.

Consulting a range of case studies, ranging from people inventing products to suit their own needs – such as Debra Latour, who created a mechanical limb to replace her own missing one – to scientists working for big companies like NASA, no stone is left unturned. The secrets of these ingenious thought processes may seem out of reach, but as Kennedy points out, a lot of things used to be. Now, not so much.

★★★★☆

The Mediterranean In History

Song of the sea

- Author: **David Abulafia**
- Publisher: **Thames & Hudson**
- Price: **£16.95 (approx $24.80)**
- Release date: **Out now**

As the self-proclaimed "first history of the Mediterranean", this book has a lot of ground (or rather, water) to cover. From the rise of the Ancient Greek Empire to the fall of Benito Mussolini, each chapter addresses a period of the sea's history, detailing the warring faiths and rival empires that have sprung up on its shores. Editor David Abulafia led a team of historians on this voyage into the past and succeeds in delivering a gripping tale. You won't realise the subject is so fascinating until you dip your toe in.

★★★★★

HOW IT WORKS

ENJOY MORE OF YOUR FAVOURITE KNOW

SUBSCRIBE

& SAVE UP TO 36%

+HOW TO LIVE BEYOND 100 THE NEW SCIENCE HELPING US TO BREAK THE AGE LIMIT
HOW IT WORKS
INSIDE
A TRAVELLER'S GUIDE TO THE SOLAR SYSTEM
100 YEARS OF WARFARE
TANK
THE EVOLUTION OF ARMOURED BA
FROM WWI TO MODERN MECHANISED
VENUS FLYTRAP
TEETH WHITENING
ARTIFICIAL ISLANDS
10 ACCIDENTAL DISCOVERIES THAT CHANGED THE WORLD
HOW IT WORKS
INSIDE
TRAVEL IN 2050
THE 8 FASTEST THINGS ON EARTH
936 FACTS AND ANSWERS INSIDE
WHAT IF...
DINOSAURS DIDN'T DIE OUT?
& 11 MORE ABSURD QUESTIONS ANSWERED WITH SCIENCE
DRONE RACING
CATS VS DOGS
POPCORN
GAS GIANTS
CHAINSAWS
+LEARN ABOUT ICE CAVES MUSCLE CRAMPS DIABETES CAR WHEELS MAN-MADE WEATHER
SAMSUNG
REVEALED THE SCIENCE OF EVERYDAY LIFE
HOW IT WORKS
INSIDE
VIRTUAL REALITY
LIGHT SPEED
JUNGLE BEASTS
CUT-THROAT PIRATES
COULD BATMAN EXIST?
HOW IT WORKS
NATURAL BORN KILLERS
TOMORROW'S CITIES
897 FACTS AND ANSWERS INSIDE
FLYING AT 80,000 FEET
SPIES IN THE SKY
12 SURPRISING FACTS ABOUT THE SOLAR SYSTEM
LG
Digital Edition

See more at: www.greatdigitalmags.com

LEDGE MAGAZINE FOR LESS WHEN YOU SUBSCRIBE!

Every issue packed with...

- Fascinating facts and mind-blowing science and tech
- Incredible photos and illustrations
- Insightful features and reviews of the latest gadgets
- Your questions answered

Why you should subscribe...

- Save up to 36% off the single issue price
- Immediate delivery to your device
- Never miss an issue
- Available across a wide range of digital devices

THE FASTEST THINGS ON EARTH
THE FASTEST THINGS ON EARTH
From supercars to sports stars, we reveal the fastest things on Earth
Built to run
The fastest human
Breaking the speed limit
BOLT

Subscribe today and take advantage of this great offer!

Download to your device now

Get in touch

Want to see your ideas on this page? Send them to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

Make a bouncy ball

Harness the power of polymers with this fun project

1 Prepare your ingredients

To make one bouncy ball you'll need half a teaspoon of borax powder, two tablespoons of warm water, one tablespoon of PVA glue (white or clear) and one tablespoon of cornflour. You can also add some food colouring and glitter to your ball if you like. It's a good idea to prepare more of each ingredient than you need, so you can make more than just one ball!

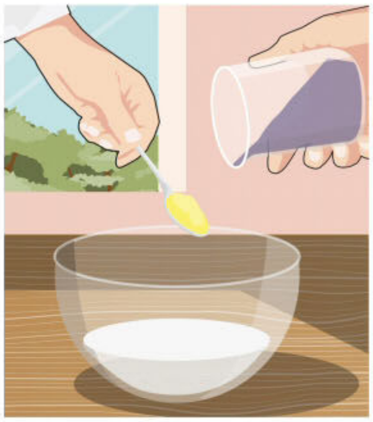
2 Mix the borax

First, place half a teaspoon of borax into a small bowl, then add the two tablespoons of water to the mixture. Stir them together until the borax is totally dissolved. If you want to give your bouncy ball a splash of colour, add around five drops of food colouring to the mixture at this point, and stir again so that everything is mixed in nicely.

3 Stir the glue in

In a separate bowl, measure out a tablespoon of glue. It will be quite thick, so make sure you get it all into the bowl. You can now add a few pinches of glitter to the glue if you want to add some sparkle to your ball. You don't need to mix the whole thing up at this stage, but you can give it a little stir so the glitter is evenly incorporated.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



4 Combine the two

To the glue, add half a teaspoon of the borax solution you just made and a tablespoon of cornflour. Wait 15 seconds, and then mix it all together with a spoon. The borax activates the polymers (molecules made of repeating units) in the glue, and they start linking to each other to form a plastic.

5 Roll and bounce!

The cornflour will help to stiffen and dry out the mixture, and as you stir and the borax activates the polymers, a blob of goo will start to form. As it stiffens even more, you can pick it up and start rolling it with your hands. Keep rolling it between your palms until a ball is formed – then leave it to one side to dry for a few minutes. When it's dry, bounce away!

In summary...

PVA glue stands for polyvinyl acetate – a polymer that reacts with the chemicals in the borax. This causes the polymer molecules to cross-link with each other, and eventually form a bouncy plastic. Experiment with the ingredient ratios for different results!

NEXT ISSUE
- Make a speaker
- Conjure a cloud

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

How to crush a can with science

Use air pressure to make recycling more efficient

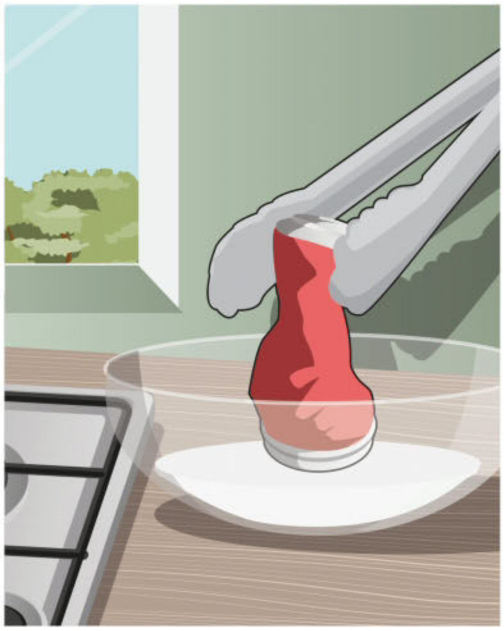
Illustrations by Edward Crooks

1 Heat it up

Pour a couple of centimetres of water into an empty drinks can and place it on a hot plate. Ask an adult to help you heat it up until the water starts to boil. When the water boils, the air inside the can is forced out through the hole in the top as water vapour starts to form inside. This lowers the air pressure inside the can, which is really important for crushing it later.

2 Prepare the water

Fill a large bowl with cold water that is close to freezing. Use ice cubes to cool the water, or put it in the freezer for an hour to make sure it's as cold as possible. The colder the water, the more effective the crushing process will be as it will make the water vapour inside the can condense more quickly. This will crush it more effectively, which is exactly what we want.

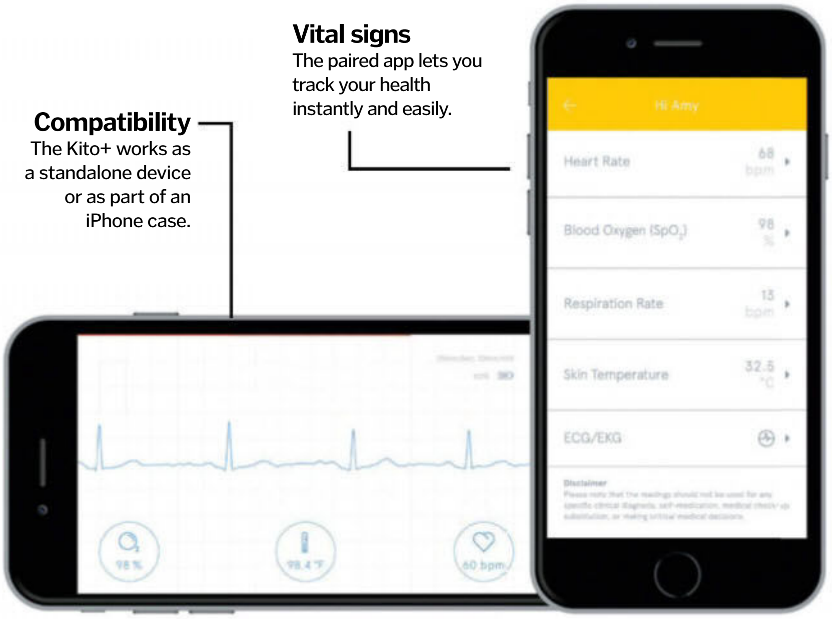


3 Flip it up

When the water inside the can has been boiling for a minute or so, and the water in the bowl is very cold, use some tongs to carefully take hold of the can, flip it upside down and quickly place the top of it into the cold water. The cold air will almost instantaneously cause the water vapour to condense back into liquid, and the air pressure inside the can to drop dramatically. The higher air pressure outside the can will push the aluminium sides inwards and crush it.

In summary…

Air constantly pushes against all objects, a force known as air pressure. However, a drinks can isn't usually crushed because the air or liquid inside it pushes back with an equal force. In other words, the air pressure is normally cancelled out. This experiment causes a pressure drop inside the can, which upsets the balance and allows the outside pressure to crush the can.



Vital signs
The paired app lets you track your health instantly and easily.

Compatibility
The Kito+ works as a standalone device or as part of an iPhone case.

WIN!

A health tracker phone case worth £99!

The Kito+ health tracker can measure your heart rate, skin temperature, blood oxygen levels, respiration rate and more. Simply hold your fingertips to the device, and in a few seconds your vital signs will appear in an app on your phone.

What was the first nuclear-powered submarine called?

a) **USS Nautilus** b) **USS Holland**

c) **USS Triton**

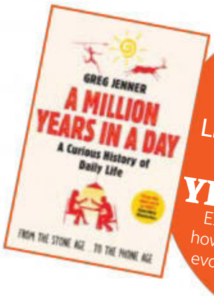
Enter online at **www.howitworksdaily.com** and one lucky reader will win!

Get in touch

Want to see your letters on this page? Send them to…

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk


GREG JENNER
A MILLION YEARS IN A DAY
A Curious History of Daily Life
FROM THE STONE AGE … TO THE PHONE AGE

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
A MILLION YEARS IN A DAY
Explore the curious history of how our everyday routines have evolved with *Horrible Histories'* Greg Jenner.

Letter of the Month

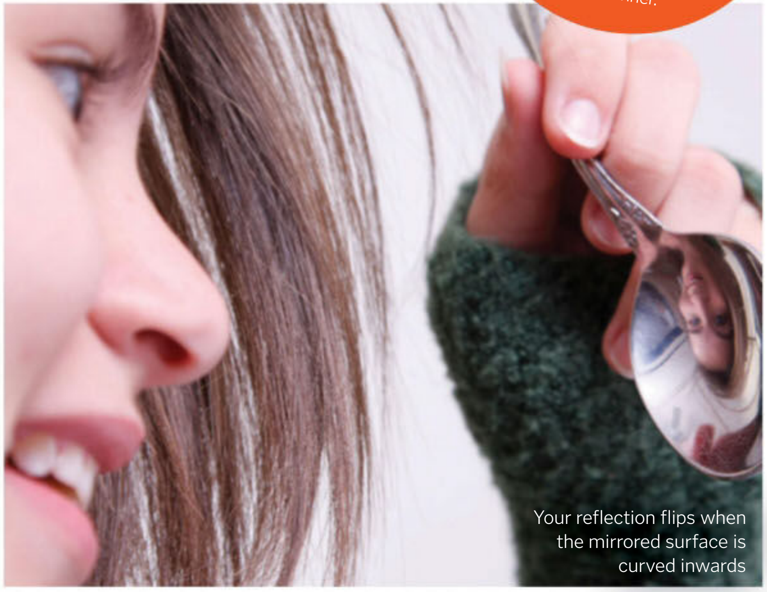
Flipped reflections

Dear **HIW,**

I've been a keen reader of your magazine for years, and find the topics both great conversation starters and excellent further reading for what I study at school. I was wondering – why is it that our reflections in spoons are upside down when looking at the concave side, but the right way up when looking at the other side?

Natasha Fisher-Pearson (aged 17)

When you look at your reflection in a flat mirror, what you're seeing are particles of light called photons being reflected directly off the surface and bouncing back to your eyes. Your brain then interprets this information as an image, which looks exactly like you. However, if you're looking at the concave reflective surface of a spoon, the image will appear to flip. This is because the curved surface reflects the light at an angle, so the photons that hit the top of the spoon deflect downwards and the ones that hit the bottom deflect upwards. Those deflected paths cross at a focal point to form an upside-down, and back-to-front, image. When you turn the spoon over and look at the convex side, your image will appear the right way up, but stretched. This is because the photons are still being deflected at an angle, but in the opposite direction.



Your reflection flips when the mirrored surface is curved inwards

What's happening on…
Twitter?

Make sure you follow us **@HowItWorksmag** for amazing facts, competitions and the latest in science & tech!

@wordsrmagic2me
There's an article that mentions where I live – the #Okanagan – in this month's issue of **@HowItWorksmag**. Cool!

@Gastrellsschool
One very happy boy in Eagles class after having his letter published in **@HowItWorksmag** #greatquestion

@BSI_press
Great piece in **@HowItWorksmag** this month with our electrical testing expert Greg Childs

@PiaMaria79
@HowItWorksmag Boys love the mag and got to admit I quite enjoy it too #never2oldtolearn

@Sara99HG
@HowItWorksmag Just subscribed to your amazing magazine! Looking forward to reading it!

Sweet cures

Dear **HIW,**

Is there evidence that eating locally produced honey can in any way help with the symptoms of hay fever?

Alex (aged 11)

Some people claim that eating fresh honey can cure hay fever because it contains pollen, which is what causes the sufferer's symptoms. The theory suggests that this would trick the body into triggering an immune response, so it produces antibodies that can fight off any invading pollen in the future. But, a study conducted by scientists at the University of Connecticut in 2002 found that sufferers reacted no differently after they had eaten honey – including a locally produced variety – when compared to those who hadn't.

It's a myth that eating local honey can cure hay fever

LEDs require hardly any energy to produce light and can last for a long time

LED illumination

Dear **HIW,**

Every time I look into a small LED there is nothing that looks like it would produce light. What exactly is producing the light?

Jeremy

LEDs contain semiconductors, such as silicon, that produce light through the movement of electrons. Silicon can be altered to form positive-type (p-type) or negative-type (n-type). P-type silicon has some electrons removed from it, to create 'holes', while n-type has extra electrons. The two types are placed next to each other in a circuit, which also contains a battery. When an electric current passes through the two types, the holes and electrons move. When an electron comes into contact with a hole, it must lose energy to combine, and this energy is released as light.

Squeaky voice

Dear **HIW,**

I've been wondering, what is it about helium that makes your voice sound higher? And why don't other gases do it?

Abigail Aust (aged 15)

When you speak, air travels up from your lungs and passes through your vocal cords, causing them to vibrate and create sound waves. This vibration causes the rest of the air in your vocal tract to vibrate, which influences the tone. When you fill your vocal tract with helium, sound waves can travel through it much faster, because helium is lighter than air. This amplifies higher frequency sounds, making your voice squeaky. The opposite would happen if you inhaled denser gases, such as xenon, as it would slow the speed of sound to make your voice deeper.

Helium doesn't change the pitch of your voice, but it does change the tone quality

Correction

Errors appeared in Issue 86. Page 31 should have read that the dinosaurs went extinct 66 million years ago, after dominating Earth for 150 million years. Facts matter to us, and we're sorry to have let you down on this occasion.

© Thinkstock; NASA; Dreamstime

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor **Jodie Tyley**
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586274
Senior Art Editor **Duncan Crook**
Deputy Editor **Jackie Snowden**
Research Editor **Katy Sheen**
Features Editor **Jo Stass**
Assistant Designer **Briony Duguid**
Editor in Chief **Dave Harfield**
Photographer **James Sheppard**
Picture Editor **Tim Hunt**
Publishing Director **Aaron Asadi**
Head of Design **Ross Andrews**

Contributors
Stephen Ashby, Sarah Bankes, Ella Carter, Alexandra Cheung, Ed Crooks, Alicea Francis, Nicholas Forder, Shanna Freeman, Rebekka Hearl, Gemma Lavender, Adrian Mann, Adam Markiewicz, Laura Mears, Philip Morris, Jonny O'Callaghan, Alex Pang, Alex Phoenix, Tobias Roetsch, Jo Smolaga, The Art Agency, Luis Villazon, Tim Williamson, Steve Wright

Cover images
Dreamstime, Getty, Nike

Photography
Alamy, Corbis, DK Images, Dreamstime, Getty, NASA, Rex Features, Science Photo Library, Thinkstock, Wikimedia, Sol 90 Images. All copyrights and trademarks are recognised and respected.

Advertising
Digital or printed media packs are available on request.

Head of Sales Hang Deretz
☎ 01202 586442
hang.deretz@imagine-publishing.co.uk

Account Manager Lee Mussell
lee.mussell@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.

Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
subscriptions@imagine-publishing.co.uk
For all subscription enquiries
☎ 0844 815 5944
Overseas +44 (0)1795 418680
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £43.50
13 issue subscription (Europe) – £53
13 issue subscription (USA) – £53
13 issue subscription (ROW) – £64

Circulation
Circulation Director Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Finance
Finance Director Marco Peroni

Founder
Group Managing Director Damian Butt

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed in the UK, Eire & the Rest of the World by: Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
☎ 0203 787 9060
www.marketforce.co.uk

Distributed in Australia by: Gordon & Gotch Australia Pty Ltd, 26 Rodborough Road, Frenchs Forest, New South Wales 2086
☎ + 61 2 9972 8800
www.gordongotch.com.au

Disclaimer
The publisher cannot accept responsibility for any unsolicited material lost or damaged in the post. All text and layout is the copyright of Imagine Publishing Ltd. Nothing in this magazine may be reproduced in whole or part without the written permission of the publisher. All copyrights are recognised and used specifically for the purpose of criticism and review. Although the magazine has endeavoured to ensure all information is correct at time of print, prices and availability may change. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to Imagine Publishing via post, email, social network or any other means, you automatically grant Imagine Publishing an irrevocable, perpetual, royalty-free licence to use the material across its entire portfolio, in print, online and digital, and to deliver the material to existing and future clients, including but not limited to international licensees for reproduction in international, licensed editions of Imagine products. Any material you submit is sent at your risk and, although every care is taken, neither Imagine Publishing nor its employees, agents or subcontractors shall be liable for the loss or damage.

© Imagine Publishing Ltd 2016

ISSN 2041-7322

IMAGINE PUBLISHING

recycle
When you have finished with this magazine please recycle it

NEXT ISSUE

Issue 88 on sale 14 July 2016

THE ICE AGE

Unearthing the lost world

Including
- Up close with the gigantic beasts
- The causes & effects
- Could it happen again?

Why our universe could be just one of many

Discover what it takes to be a fighter jet pilot

Inside the science & tech of the Olympic Games

+LEARN ABOUT

■ ICE PLANETS ■ RAINBOW MOUNTAINS ■ BLOOD TYPES ■ MAKING CHEESE
■ YOUR BRAIN ■ LADYBIRDS ■ GEOCACHING ■ SAIL ROCKETS ■ HAMMERS

© Dreamstime

FAST FACTS

Amazing trivia to blow your mind

3 MINUTES

An Airbus A380 jet takes off or lands every three minutes

THE UUV ONBOARD THE RRS SIR DAVID ATTENBOROUGH POLAR RESEARCH SHIP HAS BEEN NAMED BOATY MCBOATFACE

Professional ballet shoes contain solid wooden blocks that enable dancers to stand on the tips of their toes

VIRGIN GALACTIC'S SECOND SPACESHIPTWO WAS NAMED VSS UNITY BY PROFESSOR STEPHEN HAWKING

250

The average hen lays around 250 eggs a year

William the Conqueror's corpse exploded at his funeral due to the build up of gases in his stomach

NAVY SUBMARINE UNITS ARE OFTEN REFERRED TO AS THE 'SILENT SERVICE'

9.5

The average person in the UK spends 9.5 years watching TV in their lifetime

THE FIRST KNOWN LIGHTHOUSE WAS BUILT IN EGYPT BETWEEN 300 AND 280 BCE

Avocados ripen more quickly when a banana is nearby, because it releases ethylene gas to speed up the process

OTHER PLANETS IN OUR SOLAR SYSTEM ALSO HAVE CLOUDS. VENUS HAS CLOUDS OF SULPHUR DIOXIDE, WHILE JUPITER'S ARE MADE OF AMMONIA

IF YOU COULD DRIVE A CAR TO JUPITER AT *100KM/H*, IT WOULD TAKE YOU *3,196 YEARS* TO GET THERE

£50 MILLION ($72 MILLION)

Dyson invested £50 million ($72 million) in the development of the Supersonic hair dryer

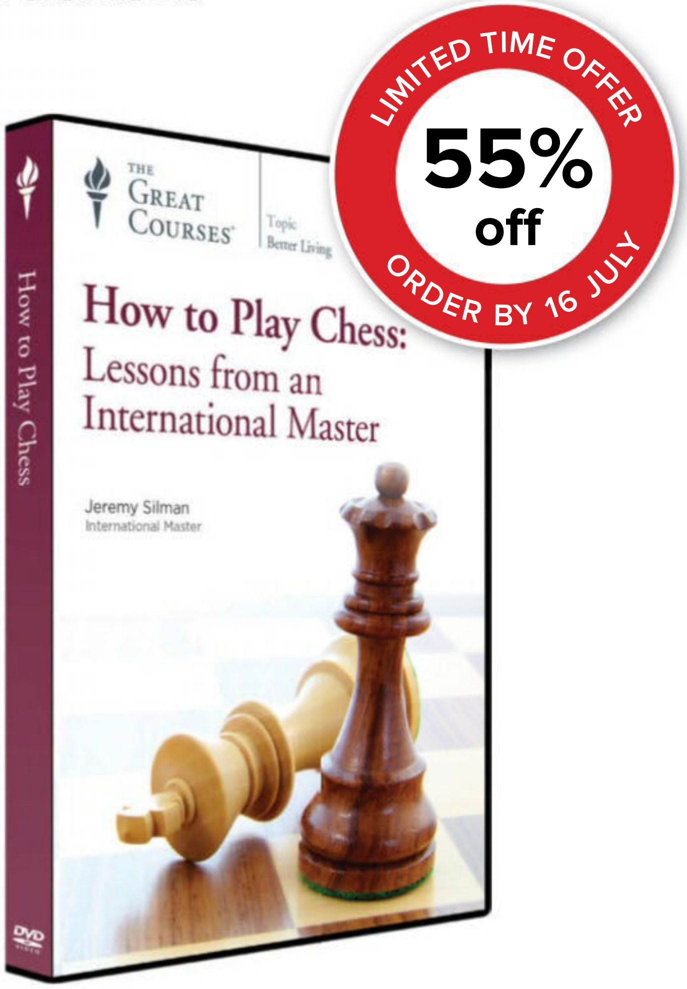
STEVE JOBS SUFFERED FROM KOUMPOUNOPHOBIA – THE FEAR OF BUTTONS

45%

Only 45 per cent of the London Underground network is in tunnels

> *"Breakthrough Starshot's nanocrafts will be propelled by a powerful laser on Earth"*

THE
GREAT
COURSES®



LIMITED TIME OFFER
55%
off
ORDER BY 16 JULY

Learn to Think like the Greatest Chess Masters

Chess is a sport, a science, an art. For more than a thousand years, people around the world have enjoyed this game of skill, tactics, and intellectual prowess. Due to the strategic nature of chess, you can learn skills that will better equip you to win every game—and this course provides guidance from an International Master to do just that.

Learn strategies, break down famous game-play, and understand how to read, speak, think, and play chess – all through the lessons of International Master Jeremy Silman. Considered the foremost author of chess instruction books, Professor Silman presents chess strategy in a way that is accessible to beginners, while offering invaluable information and insight to long-time players as well. Discover the romance and joy of the game—and get tips that will help you plan stategies, enabling you to go into any chess match with confidence.

Offer expires 16/07/16

THEGREATCOURSES.CO.UK/6HIW

0800 298 9796

How to Play Chess:
Lessons from an International Master

Taught by Jeremy Silman
INTERNATIONAL MASTER

LECTURE TITLES

1. The World of Chess
2. Secrets of the Pawns and Knights
3. Castling, Checkmate, Chess Engines, Draws
4. Must-Know Tactical Patterns in Chess
5 Chess Combinations and Kings in Check
6. Checkmate! Back-Rank, Smothered, and More
7. Checkmate against a Castled King
8. Legendary Attacking Greats of Chess
9. A Cascade of Short, Brutal Chess Games!
10. Chess Heroes of the Romantic Age
11. Open Files and the Positional Rook
12. Pawns: The Positional Soul of Chess
13. Positional Weaknesses and Targets in Chess
14. Closed and Open Positions on the Chessboard
15. Chess Statics vs. Dynamics: An Eternal Battle
16. Using Chessboard Imbalances to Create Plans
17. Legendary Teachers Who Transformed Chess
18. Chess Endgames and the King's Magical Powers
19. Kings and Pawns in Next-Level Endgames
20. Triangulation and Two Critical Rook Endgames
21. Chess Openings: The Right and Wrong Way
22. Chess Psychology and the Known Unknown
23. The Chess Amateur's Mind
24. Picking a Chess Hero

How to Play Chess:
Lessons from an International Master
Course no. 9411 | 24 lectures (30 minutes/lecture)

SAVE £30

DVD ~~£54.99~~ **NOW £24.99**
+£2.99 Postage and Packing
Priority Code: 124574

For over 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Over 550 courses available at www.TheGreatCourses.co.uk.

The Great Courses®, 2nd Floor, Mander House, Mander Centre
Wolverhampton, WV1 3NH. Terms and conditions apply.
See www.TheGreatCourses.co.uk for details.

FIRST WORLD WAR

SOMME

141 Days, 141 Lives
Read Their Stories

Available from all good bookshops

www.thehistorypress.co.uk
@TheHistoryPress @Somme_100

The History Press